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Included in this packet are the following documents:

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2. Abstract with bibliography (references) in DTIC database format. My dissertation was manuscript-based with each "chapter" having its own reference section. I combined all of these references, deleting the duplicates.

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G. Bruce Copley

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EPIDEMIOLOGIC RISK FACTORS FOR SUICIDE AND ATTEMPTED SUICIDE IN THE U.S. AIR FORCE: USING ADMINISTRATIVE DATA SYSTEMS AND MULTIPLE CAUSE OF DEATH INFORMATION TO IMPROVE PREVENTION POLICY

by

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A dissertation submitted to The Johns Hopkins University in conformity with the requirements for the degree of Doctor of Philosophy

Baltimore, Maryland
2000

ABSTRACT

In a series of retrospective studies, the investigator used data from personnel, hospitalizations, and mortality administrative information systems to elicit epidemiologic risk factors for suicide and suicide attempts occurring during 1990-1998. The reliability of the official source of military mortality information was compared against the newly-developed USAF Mortality Registry (AFMR) which uses multiple cause of death (certificate) information. The AFMR was found to be the most valid and reliable source of mortality information, largely due to the "120-day retiree" sub-cohort missed by the official data. The AFMR was subsequently used to select suicide completers into a nested case-control study in which risk factors for both suicide and attempted suicide were investigated. Exposure information was drawn from existing administrative data. Completers and attempters had several independent risk factors in

common, but the socio-demographic risk factors were altogether different. Mental health-related hospitalizations for prevalent disorders had the strongest association with suicidal behaviors. Injury-related hospitalizations for "accidents" were positively correlated with suicidal behaviors, suggesting intent misclassification, particularly in poisonings. Deployment and overseas assignment screening appeared ineffective in identifying personnel at risk of suicidal behavior. Suicide rates generally increased with increased levels of in-patient utilization. An all-military mortality registry, using the AFMR as a model, is needed. The opportunity to screen for suicidal risk factors should be taken during medical encounters. Pre-deployment and overseas assignment screening should incorporate more sensitive screening tools. Intent misclassification of injury hospitalizations is a threat to both public health policymaking and clinical interventions. (209 pages excluding CV)

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by

G. Bruce Copley

A dissertation submitted to The Johns Hopkins University in conformity with the requirements for the degree of Doctor of Philosophy

Baltimore, Maryland
May, 2000

Gordon S. Smith 10/29/00

James Tonascia 10/29/00

SUSAN BAKER 11/7/00

GUOHUA LI 11/7/00

EPIDEMIOLOGIC RISK FACTORS FOR SUICIDE AND ATTEMPTED SUICIDE IN THE U.S. AIR FORCE: USING ADMINISTRATIVE DATA SYSTEMS AND MULTIPLE CAUSE OF DEATH INFORMATION TO IMPROVE PREVENTION POLICY

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ABSTRACT

Statement of the Problem

The U.S. Air Force (USAF) and the other military service branches experienced a sustained increased rate of suicide in the early 1990s. Little is known regarding the epidemiology of suicides or suicide attempts during this period. Population-based analytical studies are needed to identify risk factors on which to target prevention efforts.

Methods

A series of retrospective studies used data from personnel, hospitalizations, and mortality administrative information systems to elicit epidemiologic risk factors for suicide and suicide attempts. The reliability of the official source of military mortality information was compared against the newly-developed Air Force Mortality Registry (AFMR) which uses multiple cause of death (certificate) information. The AFMR was used to select suicide completers into a nested case-control study in which risk factors for both suicide and attempted suicide were investigated. Exposure information was drawn from administrative data. Unconditional logistic regression controlled for several confounding variables, identifying several independent risk (or protective) factors for both outcomes.

Results

The AFMR was the most valid and reliable source of mortality information, largely due to the "120-day retiree" sub-cohort missed by the official data. Completers and attempters had several independent risk factors in common, but the socio-demographic risk factors were altogether different. Mental health-related hospitalizations for prevalent disorders comprised the bulk of the risk factors for both series. Injury-related hospitalizations were positively correlated

with suicidal behaviors, suggesting intent misclassification, particularly in poisonings. Deployment and overseas assignment screening were relatively ineffective in identifying personnel at risk of suicidal behavior. Suicide rates generally increased with increased levels of in-patient utilization.

Conclusions

Data used to administer the military's Casualty system underestimates mortality. An all-military mortality registry, using the AFMR as a model, is needed. Medical encounters should include routine screening for suicidal risk factors. Pre-deployment and overseas assignment screening should incorporate more sensitive screening tools. Intent misclassification of injury hospitalizations is a threat to both public health policymaking and clinical interventions. This study could be easily replicated throughout the Air Force to more precisely target prevention activities.

Thesis Readers: Associate Professor Gordon S. Smith (research advisor), Professor James Tonascia, Professor Susan Baker, Associate Professor Guohua Li

PREFACE

The following three papers represent the step-wise or "layered" process we used to ascertain risk factors and to build prediction models for suicide and attempted suicide in the U.S. Air Force (USAF) active duty population. The individual papers (manuscript chapters) are diverse in their objectives and methods. No single subject-matter body of literature is applicable to all chapters in this dissertation, even though the studies are linked by virtue of their being part of the research process.

A literature review exclusively on military suicidal activity would be both meager and redundant, as the vast majority of papers—including all of the analytical papers—are reviewed to some extent within our manuscripts as our process unfolds. Each analytical paper in this series contains a literature review in its *Introduction* section, limited to the paper's specific subject as is typically done in original research articles. *Discussion* sections also bring in information from other studies pertaining to our findings.

Reviewing the literature on suicidal risk factors from the general population would also be redundant, as this has already been done extremely well in several comprehensive review papers referenced throughout these manuscripts. In addition, our research proposal provided an extensive literature review of the risk factors used in developing the study design. Many of our "exposures" of interest are military-unique, thus the field of civilian-based studies did not provide much empirical evidence on which to generate hypotheses regarding those potential risk factors. In situations where we attempted to prove an existing theory (e.g., contagion), we reviewed the original theoretical research more thoroughly.

The author has included in this dissertation an additional analytical paper to "compensate" for the above deviation from the normal format of a manuscript-based dissertation. The author's advisor and the departmental academic administrator were consulted on the above, and they found this format to be acceptable.

Readers should keep in mind that the ultimate goal of this research is to ascertain epidemiologic risk factors for suicidal activity, not necessarily to infer causality. Neither the author nor his advisor is mental health clinician, thus we intend for those experts to use these findings to plan suicide prevention and intervention strategies within our general health policy recommendations. While our field of potential risk factors was limited by the constraints of the information systems, we believe these data are generally more valid than those used by most epidemiologic studies, and we *know* the military administrative data to be more complete than most epidemiologic data.

The author of this dissertation is a U.S. Air Force officer with over 15 years of experience as a public health officer and epidemiologist. Many observations made during that time are included in these manuscripts, particularly those which help explain the analytical results. Many of these explanations relate to the execution of official military policies which sometimes are written intentionally vague to encourage "best judgment" or "best practice" application. In other words, written policies may have unwritten or subjective interpretations which affect many aspects of military life. The author hopes that readers grant him some latitude in these non-referenced explanations. A comparison of regulations and policies to unwritten policy implementation practices is worthy of its own lengthy chapter; however, such exploration falls outside the objectives of this dissertation.

Chapter 1 provides an overview of our study methods and how they evolved over the course of our research process. More detailed accounts of some of these methods are contained within the individual chapters. Analytical approaches are discussed at a more theoretical level than space allowed in the to-be-published papers.

Chapter 2 documents the first phase of the research process: finding a valid source of information on the manner and cause of death on USAF servicemembers, ultimately defining both a *suicide* case series and a *suspected suicide* case series for the study period. This is the only study in this series in which original data collection was undertaken. This effort included acquiring and coding official DoD information which had been recorded on forms. The primary

investigator (PI) in these manuscripts was also the original PI on the development of the USAF's mortality registry, which is used in this study.

Chapter 3 describes the suicide case series along several axes: socio-demographics (age, sex, and rank categories), broad occupational group, time, and underlying external cause (mechanism) of death. We provide a multivariate Poisson regression model of suicide rates for the study period. The role of firearms in military suicides is explored in depth.

Chapter 4 is a case-control study of risk factors for USAF suicides, suspected suicides, and suicide attempts nested within the full USAF cohort. Our suicide and suspected suicide case series originated from the data that we had collected for our Chapter 2 study. Many of our exposure and extraneous (confounding) variables were chosen as a result of Chapter 3's findings. All of our data, and the "attempter" case series, came from existing DoD or USAF information systems. We fit multivariate logistic regression models to the data for two of the case series (completers and attempters). These models were intended for both risk factor ascertainment and event prediction. As a result of our dual models, we were able to show both differences and similarities between attempters and completers of suicide.

Chapter 5 summarizes the cumulative results of our findings and the relevance to prevention policy. Lengthier treatments of earlier discussions appear in this chapter.

The analytical manuscripts are lengthier than what may be expected to be published as a single paper, particularly Chapter 4. Several issues were analyzed and discussed in the natural progression of deeper exploration. Instead of the "this will be more thoroughly investigated in a future study" refrain, the author chose to forge ahead to more definitive conclusions in these manuscripts. Dissertation readers will gain a better understanding of these issues which an abridged manuscript could not provide. Several key topics such as suicidal contagion, pre-deployment and overseas assignment screening, and injury misclassification that receive in-depth consideration here will likely re-appear as separate articles for publication. The primary author and the second author/advisor have discussed publication strategies which will transfer sections of Chapter 4 to separate manuscripts which will be submitted for publication.

Acknowledgments

I wish to thank several individuals and agencies for allowing me to conduct this research. I should, at first, thank the leadership of the Air Force Medical Service for sponsoring and paying for my training at Johns Hopkins, particularly my former superiors who offered encouragement and support for my intentions to study injury epidemiology. The Honorable Thomas W. L. McCall, Jr., the Deputy Assistant Secretary for the Air Force for Environment, Safety, and Health, and Colonel Craig Postlewaite from that office were most instrumental in securing my Air Force sponsorship at Johns Hopkins, as was Colonel Thomas L. Cropper of the Air Force Medical Operations Agency.

My dissertation advisor, Dr. Gordon Smith, provided me an enormous amount of his expertise in classifying and analyzing injury mortality information, and provided superb editorial comments. His energy and enthusiasm for risk factor research was contagious, as his keen insights stimulated a "chain reaction" of findings. He made my "doctoral student experience" most enjoyable, and I am deeply indebted to him.

The Johns Hopkins Center for Injury Research and Policy provided me the opportunity to participate in their on-going research on military injuries. The Center's support to me and other military-sponsored researchers is unparalleled in academia. Their pursuit of effective, scientifically-based injury prevention policies for attacking the military's primary public health problem is most commendable. Professor Sue Baker inspired me (among others) to become an injury epidemiologist, and was most influential in securing my training at Johns Hopkins. The entire military establishment treasures Professor Baker as a friend.

The Air Force Institute for Environment, Safety and Occupational Health Risk Analysis provided me with data from the Air Force Mortality Registry. Special thanks to Lt Col (Dr) Roger Gibson, AFMR Program Manager, for handling the administrative and logistical arrangements

for data transfer. On the technical side, Mr. Vince Elequin of the Air Force Health Study supervised the acquisition of death certificate information and the data entry. His nosological expertise was invaluable to this researcher.

Very special thanks go to the staff at the U.S. Army Medical Surveillance Activity. Lt Col (Dr) Mark Rubertone graciously volunteered the resources for me to "harvest" some of the vast information contained within the Defense Medical Surveillance System that he deftly manages. The programming and data processing for this protocol was handled most professionally and expeditiously by Abigail Garvey, MPH, and Jeff Lange, PhD. It was indeed a pleasure to work with these individuals.

Whatever sacrifices I made time-wise on this research endeavor, my wife Linda shared the burden. I was at times more "the guy upstairs who works late in the upstairs office" than "husband". Her patience and understanding were both appreciated and absolutely necessary for the completion of my program.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

Methodology

Introduction

Suicide was the third leading cause of death in the U.S. military services during 1980–1992 (Helmkamp 1995), but by the first half of the 1990s had evolved in the second-leading cause of death after unintentional injuries in the U.S. Air Force (USAF) (Centers for Disease Control and Prevention (CDC) 1999). Despite suicide's status as a public health problem in the military, only one recent Marine Corps study (Holmes et al. 1998) was of the analytical genre from which risk factors other than socio-demographic characteristics may be obtained. Distinguishing findings from recent papers from those of not-so-recent articles is important, as the psychosocial dynamics in the military have changed drastically since the end of the military draft in 1974. The post-Cold War era beginning around 1990 introduced new stressors into the military environment, thus our objective is to fill current research needs, which are many.

Descriptive studies are more numerous, and many of these are reviewed in Chapters 3 and 4. The descriptions of the suicides have largely ignored the external cause of the suicidal injury which we consider in our studies. A few military studies on suicide offer rich descriptions or characteristics of the victims, generally from psychological autopsy information. However, these characteristics cannot be compared to the remainder of the population since information was only collected on the dead. Far less is known about risk factors for suicide attempters. Our research papers are designed to provide some of that missing information which is vital to prevention efforts. To that end, our methods include the use of population-based administrative information and an alternate source of mortality information.

The major weakness of administrative data is that the information was not collected with our questions in mind. Our methods are based on assumptions on the content and meaning of

these imperfect data, thus our findings and interpretations are also influenced heavily by our assumptions. We used the USAF active duty population during 1990–1998 as subjects in our research.

The chapters in this dissertation document our methods of acquiring risk factor information on suicide and attempted suicide—from the development of the case series to prediction models for each. The following sections provide a brief overview of each of the remaining chapters in this dissertation.

Study Overviews

Chapter 2: A Validity and Reliability Study of Two Case Series Sources

Defining suicide and developing a valid case series of suicides seems, at first glance, relatively straightforward. This initial research task, however, presented a challenge due to inconsistencies between the usual source for mortality information and a new source introduced in this study which obtains information directly from death certificates. The official, and often-used, source of mortality information in the Department of Defense (DoD) is the Worldwide Casualty System (WCS), which administratively summarizes only the manner and broad cause of death. On the other hand, we had access to the Air Force Mortality Registry (AFMR) a newly-developed source of mortality information specifically designed for research purposes. The AFMR is maintained by trained nosologists using multiple cause of death information from death certificates. We provide details of the comparison of these two data sources in Chapter 2. From that comparison we found that the AFMR gave us the most valid suicide case series.

Chapter 2 begins as a *qualitative* reliability study between the two sources of mortality information. The AFMR's information was found to be qualitatively superior, resulting in greater coding precision for the underlying cause of death. Given the AFMR's superiority and its more direct use of death certificate information, we conferred "gold standard" status on the AFMR. We then studied the validity and reliability of our own coding of the data available from WCS information using *International Classification of Diseases, Ninth Revision, Clinical Modification*

(ICD-9) codes against the AFMR's ICD codes. Our main emphasis was in comparing the ICD's *Supplementary Classification of External Causes of Injury and Poisoning* (ICD-9 E codes). We drew our primary suicide case series for the other two studies from the AFMR as a result of these comparisons, but used Casualty data to supplement the military-related information not found on death certificates. The AFMR's incorporation of multiple-cause information also allowed us to develop a case definition for "potential suicides"—unintentional injury deaths coded with external causes of death for which suicides are most easily concealed and, subsequently, misclassified. The definition is discussed in greater detail below.

CHAPTER 3: DESCRIPTIVE EPIDEMIOLOGY OF USAF SUICIDES

Having determined a valid method for defining and selecting a suicide case series (including data extraction), we report the descriptive epidemiology of suicide during the study period. Specific external causes of the suicidal injury are revealed in unprecedented detail, using the AFMR. The socio-demographic, occupational, and external causes of injury derived from this descriptive study are later used as either exposure variables or confounding variables in our Chapter 4 study.

CHAPTER 4: ANALYTICAL EPIDEMIOLOGIC STUDY OF RISK FACTORS FOR SUICIDE AND ATTEMPTED SUICIDE

Chapter 4 assesses potential risk factors for completed, potential, and attempted suicides using a nested case-control study design. While the AFMR's precise E-coding allowed us to develop a case series for "potential" suicides, the "attempter" series was defined, then selected, from the USAF's hospitalization database. The specific definitions for these two groups are given below. We analyzed completions and attempts in separate risk factor models, then assessed the models for their predictive ability. The issue of suicide misclassification is addressed analytically.

Chapter 5: Discussion of Results From All Studies

In Chapter 5, we discuss several issues in more detail than the manuscripts allowed us to do. This chapter also synthesizes our aggregate findings from the three manuscripts.

Use of Military Administrative Data

This entire research effort is innovative in that is uses a collection of existing DoD corporate databases which have had limited use in scientific studies, particularly those studying suicide and parasuicide. We used personal identifiers (social security number and name) to link the various databases. The linkage of analogous civilian data, at least in the U.S., would not be possible for a variety of reasons beyond discussion here. Public-use data files are usually superb for their intended use, but do not include confidential identifiers on which to link with other databases. Another advantage of using military data is the completeness of the information and the number of data elements maintained on all subjects. The vast amount of socio-demographic information on individuals allowed us to statistically control for a wide array of potential confounders. Thus, a major threat to validity was largely contained.

Study Hypotheses

Only the case-control study in Chapter 4 formally tests hypotheses; however, each study implicitly does so when comparisons are made. Informal hypotheses tested in Chapters 2 and 3 represent the authors' *a priori* "expected" results.

Table 1. Hypotheses tested, rationale for testing, and type of test used.

Hypothesis	Rationale for inclusion	Test(s)
Chapter 2. Mortality Database Comparison		
H1: Significant disagreement exists between the two primary sources of mortality data regarding the manner and cause of death.	The official DoD mortality data source (Casualty) administratively summarizes the underlying cause of death, resulting in a loss of multiple cause of death information loss from death certificates.	Interrater reliability (Kappa, both weighted and unweighted), various levels of nosology/coding.
H2: The Air Force Mortality Registry (AFMR) has the most precise E codes on injury-related deaths (incl suicides).	AFMR is maintained by trained nosologists who code for multiple cause of death.	Proportion of deaths in each qualitative category; accuracy and sensitivity; AFMR "gold standard".
Chapter 3. Suicide Descriptive		
H1: Suicide is not distributed randomly among all USAF socio-demographic groups.	Previous military suicide studies report gender, racial, and rank differences; little known of risk factor independence however.	Crude rate comparisons. Poisson multivariate regression modeling, adjusting for sex, rank, & race.
H2: The frequency of suicide by means of firearms is sex, age- , and rank-dependent.	Older adults and females in civilian populations are more likely to use non-firearm means. Indicator of level of intent and intent to conceal the suicide.	Crude analysis of gun-nongun ratio in suicide by sex, rank, and age.

Hypothesis	Rationale for inclusion	Test(s)
	Chapter 4. Suicide and Attempted Suicide Case-Control	
H1: Stressful military assignments (e.g., deployment, air combat base, base slated for closure, overseas bases) are independent proximal[1] risk factors for suicide and parasuicide.	Stressful life events are recognized or suspected risk factors for (para)suicide. Certain military assignments are stressful. Their proximity to the suicidal act would suggest that they are triggering mechanisms.	Multivariate (MV) logistic regression, ascertaining the independent statistical effects (odds ratio for caseness controlling for other variables).
H2: Mental health- and medically-related hospitalization utilization is positively associated with suicide and attempted suicide.	Psychiatric and medical problems are risk factors for suicide in civilian studies. Hospitalized cases' higher severity should logically increase both the diagnostic validity and the statistical association.	MV logistic regression, finding independent statistical effects (odds ratio [OR] for caseness controlling for other variables). Stratified by utilization level.
H3: Suicide completions and attempts cluster by time and location (USAF base or unit).	Limited evidence of clustering in U.S. population; even less studied in military populations. Measures "contagion" influence.	Same analysis as above. Separate terms for each level of *time since exposure*; events by base.

[1] Occurring within three months of the suicidal event.

Hypothesis	Rationale for inclusion	Test(s)
H4: Past hospitalization for apparent unintentional injury is positively associated with suicide, particularly those with high potential for concealment and misclassification.	Evidence of this relationship exits in the civilian population, particularly for external causes of injuries which may represent prior concealed suicide attempts (e.g., poisonings, certain types of motor vehicle mishaps, etc.).	MV logistic regression, finding the independent statistical effects (OR for caseness controlling for other variables). Stratification by external cause of previous injury, and hospital utilization level.
H5: Suicide completions and suicide attempts do not differ in their risk factor profile (statistical associations with exposure variables).	Prior attempts are strongly related to completions in civilian population, indicating a shared risk profile.	Separate multivariate logistical regression models for the two outcomes. Compare prediction equations.

Study Design

Each study in this series employs a different study design, but they are all retrospectively based. Our research dataset included nine potential years of "observations" which were documented in the databases. In comparing mortality data sources (Chapter 2) we essentially took a cumulative incidence approach, summing the number of deaths by various classification schemes over some more inclusive category's number of deaths during the study period. Our descriptive study of suicide (Chapter 3) was of a retrospective-cohort design where person-time was the denominator on which incidence rates and rate ratios were calculated.

The case-control study on (para)suicidal risk factors seen in Chapter 4 is nested within the USAF cohort and looks backward for exposure information. DoD databases would just have easily facilitated a retrospective-cohort or follow-up study design using person-time for Chapter 4. However, the case-control method of study was the most efficient for the purposes of our

study which included assessing several hypothetical risk factors for their statistical association with any of the three dependent variables (suicide completions, potential suicides, and suicide attempts). Each of these variables represent relatively rare events, thus a case-control design was most appropriate. Several exposures of interest in this study had never been assessed before, thus one study encompassing all such factors was more expedient than conducting several follow-up studies. Many such "exposed cohorts" would have been small in number. These small cohorts would likely have resulted in significant loss to follow-up in a dynamic population in which several mechanisms for information loss (e.g., multiple types of administrative discharges, medical retirements, voluntary separations, other manners of death) compete with the study's analytical endpoints, suicide and attempted suicide. We used incidence-density, or risk-set, sampling of controls, using a 1:4 case:control ratio for each of the three case series.

Study Population

Our target population is the U.S. military, using the 1990–1998 U.S. Air Force as a study population. The first two studies are denominator-based studies. We restricted these studies to the active duty component (as opposed to Reserves and Air National Guard [ANG]) of the USAF population for two reasons. First, we did not wish to include numerators which were not included in the denominator when comparing mortality or suicide incidence. Reserves and ANG personnel commonly serve on active duty for a limited engagement, contributing to the denominator only briefly. Their death could have occurred during a time when they were "off the rolls" of the active force, perhaps during monthly weekend drills in hometowns across the U.S. Our demographic data contained only active duty person-time contribution, thus we limited our numerators to such. Secondly, the manner or cause of death in Reserves and ANG personnel may have had no relationship to military service, particularly for unintentional injuries. Inherent in the type of research that we have undertaken is the assumption that some proportion of the mortality is attributable to the military influence or environment. That

assumption is far weaker in a sub-cohort which is "civilian" for all but a limited number of days per year.

We expanded the scope of our study population to include Reserves/ANG for the case-control study on (para)suicidal risk factors, as neither the analysis nor the validity of the study was compromised by denominator issues, given our study design and sampling methods (See Chapter 4). The suicide case series includes seven Reserves/ANG personnel who committed suicide while on active duty, and the control group includes anyone who was on active duty at the time of the cases' suicide. Each of those individuals had contributed significant active duty person-time, thus each had information to contribute that was based on their military experiences. Additionally, potential risk factors for suicide such as deployment are frequently as common in Reserves/ANG as the active duty population. Non-military readers should realize that many individuals who are in the Reserves component serve as *de facto* active duty for up to 20 years depending on their unique skills and the military's need for that skill. The chance of choosing a non-informative Reservist/ANG as a control (i.e., a "traditional" Reservist) is remote since the probability of randomly selecting a control is proportional to his/her time spent serving on active duty.

Numerators (Events)

Numerators for the first two descriptive studies vary by the level of analysis, being as general as "all deaths" or as specific as "suicides". The case-control study was based on three types of events, or dependent variables: completed suicides, potential suicides, and attempted suicides. The ICD-9 E codes allowed us to construct a case series of "potential suicides", i.e., deaths sustained by injuries which were coded as unintentional or of undetermined intent, but could actually have been suicides. The case series for Chapter 4's attempter series was constructed from the hospitalization database which uses an injury coding system unique to the military of North Atlantic Treaty Organization (NATO) countries, the NATO Standardization Agreement (STANAG 2050) (Amoroso et al. 2000). STANAG is a two-part code consisting of a

trauma code and an injury code. The trauma code is basically an intent category (e.g., intentional, unintentional) while the injury code is akin to the ICD scheme's E code for external cause of injury. Our attempter case series was defined as persons who were hospitalized with a trauma code indicating that the injury was "intentionally self-inflicted". See Chapter 4 for more detailed information on case definitions.

Denominators

The two descriptive studies use cumulative mortality (incidence) in the active duty USAF population as denominators. These denominators were partitioned by whatever scheme was germane to the question at hand, e.g., annual mortality, annual suicides, total injury-related deaths, total deaths common to both mortality datasets, etc. Our second study uses person-time (in years) for its denominator.

The case-control study in Chapter 4 did not use denominators per se, but used a control group chosen from the general USAF population. Official DoD personnel data was used to construct and sample from a cross-section, or risk-set, of the population which was on active duty at the time of the cases' event (suicide, potential suicide, or attempted suicide). The control group was taken from what would have been the denominator had this study been prospective in its study design.

Primary Data Sources

DEFENSE MANPOWER DATA CENTER (DMDC) DATABASES

DMDC databases maintain vast amounts of personnel data on military personnel dating back to 1980. Various administrative databases are aggregated into an active duty master file for each service. The data for this study is an extract of the master file for USAF which enumerates the entire military population and documents each servicemember's person-month contribution to the cohort. Variables include but are not limited to age, gender, race, occupational specialty, race-ethnicity, marital status, educational attainment level, assigned unit

and location (postal zip code), and length of time in service. These files are archived, not overwritten, so those data on individuals no longer on active duty remain available. This data system is compatible with longitudinal dataset construction, discussed below.

DMDC master files provided all of the person-time denominator data for this study except for the occupational groupings used in Chapter 2. The control group for the suicide case-control risk factor study was chosen from this database representing the reference population at the time of each case-event. DMDC data also provided socio-demographic and assignment data for all cases and controls in the Chapter 4 study.

HOSPITALIZATION (STANDARD INPATIENT DATA REGISTRY [SIDR])

This database serves two purposes in Chapter 4: to define the "suicide attempter" case series, and to contribute explanatory variables in the form of various types of hospitalizations for both cases (suicides, suspected suicides, and attempted suicides) and their controls. Data on active duty inpatient admissions (hospitalizations) are maintained in an administrative database modeled according to a federal Standardized Inpatient Data Registry (SIDR) developed as a military-wide standard. While a SIDR-like database has been maintained for the USAF since 1980, the data collection system underwent a major transition in 1989, thus only data from 1990 was used to assure data comparability. Among the changes to the SIDR were the migration from ICD-8 to ICD-9, additional data elements, and changes in some data element definitions which were incompatible with the other services. The variables of interest in this dataset are diagnoses using ICD-9 CM codes, STANAG trauma and injury codes for injury hospitalizations. All U.S. military medical facilities use the STANAG coding scheme instead of the ICD E code supplement to assign external cause. Likewise, SIDR includes STANAG codes for those military injuries treated at civilian hospitals, as the ICD codes are translated into STANAG.

AIR FORCE MORTALITY REGISTRY (AFMR)

The AFMR provides the primary data for our numerators (the case series) over the study period. This mortality research database is compiled and maintained by the Air Force

Health Study (AFHS) office, and represents the primary data source for these studies. AFHS, also known as "Ranch Hand" is the congressionally-mandated research unit devoted to assessing health risks due to a dioxin-containing defoliant, "Agent Orange" used during the Vietnam Conflict. Ranch Hand, as part of its mortality surveillance on the Vietnam-era cohort, collects active duty death certificates from the death-certifying jurisdictions around the world. Data were not available for 1990 as construction of that database was still ongoing at the time this study began. The events (dependent variables) were drawn from the AFMR, except for calendar year 1990 when Casualty data provided that information on each death.

Ranch Hand nosologists code the death certificates for both underlying and contributing causes, then derive a valid underlying cause of death using algorithms developed by the National Center for Health Statistics (NCHS) which are included in a software and data entry system called the *Automated Classification of Medical Entities*, or ACME (Rosenberg H. M. and Kochanek K. D 1995). Their nosologists have the appropriate level of NCHS training for this level of coding, and they are highly experienced. Injury-related deaths receive both ICD-9 E-codes and nature of injury (N) codes. ACME occasionally "overturns" a sometimes illogical or invalid underlying cause as specified by the certifying official, as ACME provides a more logical determination of the underlying using the complete field (multiple-cause) of death certificate data. No data is available from Ranch Hand on the proportion of overturned decisions.

The AFMR contains the following data elements: personal identifiers, date of death, date of birth, manner of death, causes of death (described above, in ICD-9 format), rank, sex, race, and whether the individual had been retired from the USAF for up to 120 days. The "120-day retiree" categorization includes, but is not limited to, individuals who are medically retired due to either illness or injury in which death is imminent, or when the effects of the injury/illness linger (i.e., death- or disability-expectant conditions), but who may remain in DoD hospitals due to the seriousness of those conditions. A typical case would be someone who sustained a severe head injury from a suicidal jump and died, say, a few days after his/her injury. In imminent cases, the retirement process is usually expeditious, with the goal of retiring the

servicemember before death. This administrative action is generally taken to serve the financial interests of the surviving family members, as a deceased member's retirement benefits exceed his/her "death benefit" over the long term. The official DoD casualty-recording system does not document these deaths (see below); however, that sub-cohort contributed 11 additional suicides to Chapter 4

The AFMR's detailed multiple cause of death information allowed us to construct a definition for, and a case series of, "potential" suicides. Our criteria for selection into this category are explained below.

DoD Casualty (Mortality) System

DoD's official Worldwide Casualty System (WCS) is administered by the Directorate of Information Operations Reports (DIOR). WCS compiles each service's administrative data on active duty casualties from the services' Casualty offices. For our research we used WCS' mortality files (there are other, non-fatal types of casualties).

Casualty data are a supplemental information source in our studies, but are the exclusive source of mortality information for calendar year 1990 since AFMR data were not available for that year. Casualty data were found in Chapter 2 to be a reliable substitute for AFMR data for most manners and broad causes of injury-related deaths. Casualty data also provided the source of occupational codes for the entire case series, as the AFMR lacks that information. Casualty information is also unique in that it provides the servicemember's component (active, Reserves, or ANG) which allowed us to differentiate between those individuals who were in the Active component versus any non-Active component of the USAF. This is important since registered deaths in both Casualty and AFMR include USAF Reserves and Air National Guard deaths.

The WCS acquires its Casualty (mortality) data from the DoD Form 1300, Report of Casualty (DD1300) on which base-level personnel officials annotate the underlying cause of death from a copy of a deceased servicemember's official death certificate. Each deceased servicemember's survivors are entitled to a "death benefit" which is activated upon completion

of the DD1300. The survivor-beneficiary is required to furnish an official copy of the deceased servicemember's death certificate to receive the benefit. USAF base-level Casualty personnel transcribe information they feel is relevant (to their administrative function) from the death certificate on the cause and circumstances of the death onto the DD1300. This information is subsequently transmitted to the WCS which maintains the electronic database and a hard copy of the DD1300 on each death. The electronic data file contains unique identifiers (names and social security numbers), socio-demographic information, and the manner (intent category) of death, but does not include information on the cause of death. The manner of death listed on the DD1300 is entered into an electronic WCS database, using an administrative coding scheme which only classifies deaths into seven broad manners of death (e.g., illness, accident, suicide, homicide, terrorist, hostile action, and, undetermined) along with a "pending" category. DD1300 information also includes a free-text extract of what the personnel officials consider to be the underlying cause of death as cited from the official death certificate. This information is not coded in any fashion, and is not electronically linked to the administrative manner of death code discussed above. The electronic data does not provide more specific causes of death (e.g., gunshot wound or drowning). Casualty data thus consists of two unlinked elements: the administrative code for the manner of death, and a transcribed version of the underlying cause of death on the hard copies of the official DD1300.

A most informative third element of WCS' information-gathering function also exists: detailed summaries of internal USAF forensic investigations of deaths due to unnatural causes. Our information was limited to female deaths in which the manner of death was something other than illness-related. These "internal reports" were available only as a result of another ongoing research effort within the Johns Hopkins Center for Injury Research and Policy on females in the military. This information was used in a limited three-way comparison of the manner and cause of death in Chapter 2. The results of that study indicated that the internal report information may have been occasionally introduced into the WCS's official version on the cause and circumstances of death (as indicated on the DD1300s) despite official directions specifying

that only information on the death certificate should be used. We explored that issue further in 28 female injury-related deaths, in Chapter 2.

Defense Medical Surveillance System (DMSS)

Most of our demographic and exposure data for Chapter 4 was acquired through the U.S. Army Medical Surveillance Activity (AMSA), an agency which operates the Defense Medical Surveillance System (DMSS). The DMSS is a modern longitudinal relational database which links a wide array of DoD administrative databases, using personal identifiers (name and social security number). DMDC electronically sends certain data elements to AMSA each month, and each servicemember's composite DMSS record "grows". AMSA also acquires each service's hospitalization data from their respective SIDR-based systems, and they receive mortality/casualty data from the WCS.

On-Line Supplemental Data Sources

We used the Air Force Personnel Center's (AFPC's) Interactive Demographic Analysis System (IDEAS) (U.S. Air Force Personnel Center 1999) to acquire denominators which matched the AFMR/Casualty numerators in the descriptive study in Chapter 3. This data becomes assimilated into DMDC personnel data during which DMDC re-categorizes the information according to a DoD standard format. Our occupational categorizations were generally non-standard, so we used the more parochial AFPC information for denominators. IDEAS posts their personnel totals as of 30 September of each year, not in person-years. However, a comparison of sex, age, and rank from IDEAS annual cumulative personnel totals to those descriptor totals from DMDC (Defense Manpower Data Center (DMDC) 1999) person-years data indicated the differences were negligible—generally plus or minus less than a half percent across all categories. Given that all denominators are interpretable as person-time, we were able to compute mortality rate ratios for Chapter 2. AFPC does not post data for years prior to 1994; therefore, analyses of mortality rates by occupation were constrained to those years for which data was available. We used DMDC's on-line Information Delivery System

(DMDC 1999) to supplement data obtained from IDEAS in acquiring denominators requiring an alternate categorization scheme.

Table 2 below provides a synopsis of our data elements and their origin.

Table 2. Study variables, source of data, and variable characterization/coding.

Variable	Data Source	Type and values
Dependent variables		
manner of death	Casualty	nominal (illness; undetermined; pending; injury: unintentional, hostile, terrorism, homicide, suicide)
cause and date of death	AFMR* & Casualty†	numeric ICD N and E codes except for date, investigator categorized as nominal
STANAG trauma code	Hospitalization	numeric STANAG code = 4 indicating "intentionally self-inflicted injury admission", i.e, suicide attempt; recoded into binary (nominal)
STANAG injury code	Hospitalization	E code-like classification for external cause of injury hospitalization; recoded as nominal
** AFMR provides multiple-cause (underlying and contributory) of death coded by nosologists using NCHS algorithms. ICD codes allowed assignment of a manner of death. † E codes came from investigators' coding of information derived from Casualty electronic data on manner of death and the text transposition of the underlying cause of death on hard copies of the Report of Casualty (DD Form 1300).*		
Socio-demographics		
sex	DMDC	nominal (female, male)
race/ethnicity	DMDC	nominal (white, black, Hispanic, etc.)
education level	DMDC	ordinal categories (no HS diploma, HS grad/GED, college grad or higher)
marital status	DMDC	nominal (single, married, no longer married, unknown)
pay grade/military rank	DMDC & AFMR & Casualty	continuous recoded into ordinal categories (E1-3, E 4-6, . . . O1-3, O4-6 . . .) & binary nominal categories (officer, enlisted)
age at death	AFMR	continuous, recoded into appropriate ordinal format for analyses
occupation	DMDC & Casualty	numeric codes recoded into nominal (operators, maintainers, security, medical, etc)

Variable	Data Source	Type and values
year entered service	DMDC	numeric format
years in service	DMDC	continuous variable recoded into appropriate ordinal format for analyses
120-day retiree	AFMR	nominal indicator for deaths occurring in retired servicemembers between the retirement date and 120 days post-retirement
service component	Casualty	nominal (Active Duty, Reserves, Air National Guard)
Exposures		
diagnosis/admission code (ICD)	SIDR	numeric ICD N- and E-codes recoded into nominal categories of ICD ranges of interest for admissions (non-injury, psychiatric [by sub-category, e.g., alcohol-related, depression], injury-related, previous suicide attempt).
admission date	SIDR	date format
unit/location (by zip code)	DMDC	numeric zip code of servicemember's unit at time of death or time of selection as a control; investigator-created nominal categories of overseas by region, combat aircraft base, base slated for closure
deployment	DMDC	nominal (Persian Gulf, Rwanda, Haiti, Bosnia)
deployment date	DMDC	date format

Dataset Construction, Descriptive Studies (Chapters 2 and 3)

Ranch Hand compiled the AFMR data for 1991–1998, providing an electronic copy to the principle investigator (GBC). The investigator segregated those deaths with E codes (i.e., injury-related deaths) from non-injury related deaths. The injury-related deaths were then categorized and encoded into one of five injury-related intent categories corresponding to the

WCS' official regime—unintentional injury (aka "accident"), self-inflicted (suicide), homicide, hostile fire, terrorism. We added *injury of undetermined intent* (IUI) an ICD-9 category that the WCS lacks. Instead, the WCS uses *undetermined cause*, which includes IUI. Non E-coded deaths in AFMR were categorized and encoded simply as "illness". We also created an "unknown cause" category to receive those deaths coded in the AFMR as N797–N799, *ill-defined and unknown causes of mortality.*

We compiled a separate dataset from the electronic version of the 1990 Casualty files along with information from hard copies of DoD's Report of Casualty (DD Form 1300). From the two-part Casualty information described above, we E-coded each Casualty-listed injury-related death, coding to the highest possible level of specificity. For illness-related deaths, we just assigned the WCS administrative code for the manner of death. In essence, we created a dataset paralleling the AFMR.

The first step in this coding process was using the Casualty system's manner of death administrative code to place a case into the appropriate section within the ICD-9 E coding scheme. For instance, a record for which Casualty had coded "suicide" limited the search for an appropriate E-code to the E950–E959 range. The DD1300 text information formed the basis for the more exact E code within that range. This method denotes that we did not contradict the Casualty system's manner of death regardless of any information on the DD1300 which may have inferred an alternate manner of death, as we wanted to maintain the integrity of that data for comparative purposes. Deaths for which the manner of death was coded "illness" were not coded for underlying cause. The exception to this rule was when the DD1300 indicated that the actual manner and cause of death was ambiguous, which warranted an ICD-9 N code of 799.9 (ill-defined and unknown causes).

The two mortality datasets were merged on each case's social security number, with the AFMR being designated as the master dataset in which the information was held inviolate for the merge. Thus no overwriting of AFMR data occurred as only the specified missing information (occupation, location of death) was pulled in from Casualty. After the merge, those

AFMR-indicated homicides which, according to the Casualty files, were the result of terrorism, were recoded as "terrorism" in the combined dataset. The AFMR uses the ICD-9 coding scheme which does not distinguish between the two types of homicides. Our dataset's primary analytical accomplishment was the side-by-side columns of ICD-9 codes for the underlying causes of death, one from the AFMR and the other from the Casualty information. This was the comparison we were most interested in for the study in Chapter 2.

No missing cases were noted in the combined dataset after the merge. However, the AFMR recorded 12 active duty deaths, in addition to the 120-day retirees, not found in the Casualty files, thus the AFMR is the more sensitive of the two systems with regard to death ascertainment. There is no obvious explanation for this discrepancy, but given the certainty of each case's death (a certified official copy of the actual death certificate), and that these individuals were officially classified as active duty by the appropriate USAF agency, we find no reason to dispute the AFMR's case findings. Additionally, we believe the AFMR most correctly presents the numerators for this study and that there are no missing deaths in this data. These issues are explored in Chapter 2.

Missing descriptors in the combined (AFMR-WCS) dataset were rare: no missing data for age, sex, or rank; one death missing an occupational code in the KIA category (4.7 percent); five deaths missing a race-ethnic code for unintentional injury deaths (0.5 percent), and two (0.4 percent) missing race-ethnic within the suicide category. Denominator data were stratified to match the descriptors from the case series (e.g., by decedents' year of death, sex, race, occupation, and rank category), and assembled in a spreadsheet. The numerator and denominator stratified data were merged into a working dataset for analyses which appear in Chapter 3.

Dataset Construction, Nested Case-Control Study (Chapter 4)

CASES

The dataset on which the case-control study in Chapter 4 was created by programmers at AMSA, based on the primary investigator's instructions. Along with programming instructions, the investigators provided AMSA with a roster of two (completers, attempters) of the three suicide case series below, identifying individuals by name and social security number:

Completed suicides consisted of active duty and non-active duty subjects who committed suicide according to any of the three sources of information: AFMR (the primary source), Casualty/DD1300, and the female subset of Casualty internal reports. We felt that if suicide was specified in any of these three data sources, that the probability of a true suicide was high. In Chapter 2's comparison of the two main data sources, we found 98 percent agreement on the manner of death, thus the differences were minor. The completer roster contained 502 records, 480 of which were considered in AFMR (from death certificates only) to be suicides (E950–E959), three of which were not listed in Casualty as deceased. The 120-day retiree sub-cohort of the AFMR added 11 suicides to the series. Three non-suicide deaths in AFMR *were* classified as suicides in Casualty (manner of death = "suicide"), as was one death for which the internal report (but neither the electronic version of Casualty nor the AFMR) listed as suicide. The remainder of the completers came from the seven Reservist suicides during the period.

Potential suicides included 84 subjects based on a case definition from the AFMR which included any death by undetermined intent (E980–E989), unintentional firearm (E922), unintentional poisonings (E860–E869), unintentional drowning (E910), and ill-defined and unknown causes of death (N797–N799). This list was based on our earlier literature view of where there had been validity problems regarding the coding of injury intent. AMSA supplemented this case series with two intentionally self-inflicted deaths recorded in the hospitalization database—apparent suicidal deaths occurring in in-patients not already listed as

"suicide" in the completer list, bringing the "potential suicide" total to 86. These two additional deaths could not be linked to death certificate information in the AFMR since our confidentiality protection scheme deleted unique identifiers.

"Suicide attempts" were created from DMSS data according to our programming instructions. "Attempters" comprised of persons who were hospitalized with an intentionally self-inflicted injury ("suicide attempt-like" = STANAG Trauma Code "4" in SIDR), but who *did not die* as a result of injuries sustained during that episode of care, and never died from suicide or suspected suicide during the study period. Furthermore, repeat attempters were not considered to be a case upon their first such hospitalization (but single episode attempters were). In other words, repeat attempters become a case upon their most recent admission with trauma code 4. Our rationale was that we did not want to count repeat attempters and their information more than once. ASMA cross-referenced Code 4 records with Casualty data and our AFMR listing, ensuring that the attempters were not mixed with either of the other two case series which consisted only of deceased individuals.

Controls

Each case series was assigned its own control group at a 1:4 case:control ratio. All controls were randomly selected from "those who could have experienced the event" at the time of each case's event (completed, suspected or attempted suicide), using DMDC data. In other words, controls were chosen from the cohort of USAF personnel on active duty on the date of each case's event. This is referred to as incidence-density, or risk-set, sampling from the general population in which controls were not restricted to non-cases. The probability of control selection was proportional to their contribution of person-time during the study period.

Exposure Measurement

We did not constrain the case or control selection to any study entry requirements, e.g., years of observation time during the study period, so we likewise did not impose any specifications on the exposure variables. Some study subjects had a full nine years of

observation (exposure history) while others had but a few weeks of observation. We controlled for these inequities during the analysis. We provided AMSA instructions for linking to and searching the personnel and hospitalization databases for the exposure variables introduced above, using social security numbers and names for linkage.

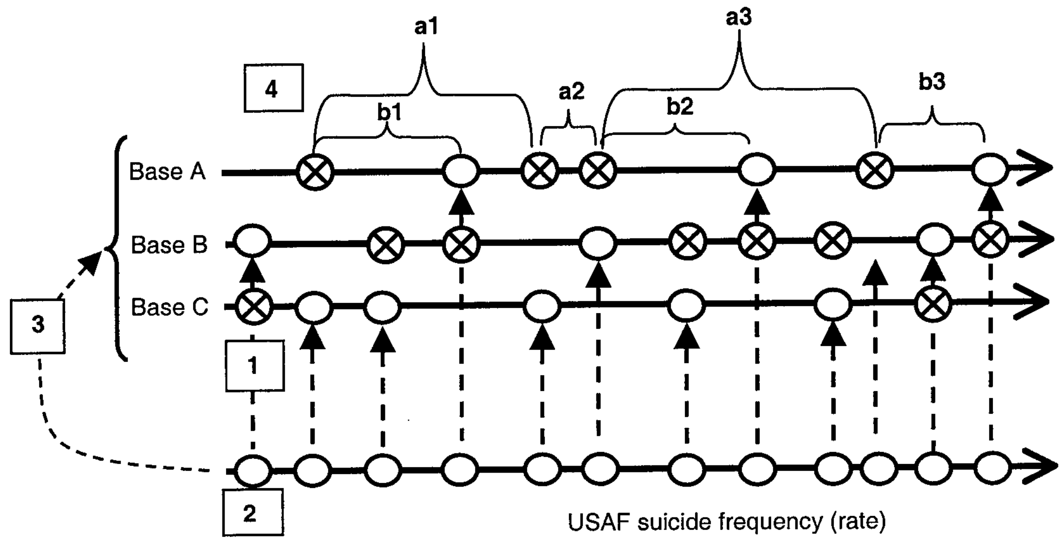
Medical Hospitalizations

We excluded medical (non-injury, non-mental health) hospitalizations for "preventive" removal of wisdom teeth (N520)—a common USAF practice that ended in 1999—and dentofacial abnormalities (N524). Also excluded were female hospitalizations for childbirth (N650–N654) and sterilization (V25.2). Hospitalizations were also censored if they were "event-defining", i.e., those hospitalizations on which the case definition for "attempters" was based, or intentional injury hospitalizations that ended as in-patient deaths (suicides). These hospitalizations, however, were analyzed separately for their statistical relation to suicide and attempted suicide.

Time Since (Para)suicidal Exposure

This variable was created to assess the statistical relation with suicidality, if any, that a single (para)suicidal act (completion or attempt) generates on a base cohort as time progresses. Our sampling plan and study design did not allow us to assess this prospectively by measuring and comparing time-to-event in two specified sub-cohorts. We instead created a similar variable by breaking the linkage between cases and controls, then assigning them to their actual base or unit (AU) to which they from which they were drawn as a study subject (Figure1). Our analytical strategy was to compare the *time since exposed to a suicidal act* between cases and controls. More specifically, controls represent the incidence density in the USAF, i.e., what the tempo would have been at the AU if events had occurred at the same frequency as USAF overall. Cases, on the other hand, represent each base's actual frequency (rate) of events. This is shown graphically in Figure 1.

Figure 1. Construction of TIME SINCE EXPOSED TO (PARA)SUICIDE.



1. Suicide or attempted suicide (event) ⊗ occurs at Base A, B, or C.
2. Controls (4) ○ selected randomly from population at time of each event (only 1 per event shown).
3. Controls placed into their actual unit/base of assignment ordered by the date they were selected.
4. Time since exposure (distance) measured: (a1–a3) distance between 2 events in unit; (b1–b3) distance between an unit event and events occurring elsewhere (control) throughout USAF.

The variable *time since exposed to a suicidal event* was arbitarily categorized into four categories: 0–7 days, 8–30 days, 31–90 days, and beyond 90 days (reference category). We then measured the odds of being a case (completer or attempter) or control in each of the categorized *time since last exposed* "exposure" categories, relative to the most remote exposure category, beyond 90 days. Exposures were constrained to a 90-day period to reduce the inherent errors in assigning case-subjects' exposure time to the correct base, as military relocations are frequent. Our use of the term "index" in this explanation merely refers to the first of the paired events, not the first case initiating an epidemic. Index events included both completions and attempts as a result of our theoretical construct of hypothetical contagion in the USAF.

Inherent to this variable's construction is that *time since exposure* could not be calculated for observations which were either "first events" or "first sampled" (for controls) at

each base, since there were no index observations prior to the starting period for this study. In other words, we could not calculate a real *time since exposure* until after a base experienced its first suicidal event. In several instances, a string of controls was sampled prior to a first event. Neither those controls nor the first suicidal events were given a value for *time since exposure.* For prediction modeling, these observations were assigned imputed values for *time since exposure* based on the median value for the case-control series (e.g., attempters or completers) given that the observation was either a case or control. Otherwise, 112 observations offering other information needed to predict these events would have been excluded from the models.

The odds ratios for each *time since exposed* category measure the statistical relation with suicidality that a single event (completion or attempt) generates on a unit's cohort as post-exposure time advances. Controls selected from the same assigned unit (AU) as cases were ineligible for this analysis since they were drawn on the same day. The elapsed time between suicidal events (*i*) at each AU was computed as,

[event date for serial suicidal event at AU, *i*] – [event date for serial suicide event at AU, *i*-1] (1),

while the starting point for *controls'* elapsed time began on the event date of its matched case at "Unit/Base X", the *case's* assignment location in which the base or unit has its own postal zip code:

[matched case-event date at Unit X] – [event date for index/serial suicide event at AU, *i*-1] (2),

where *i* represents any index suicidal event in a base-specific series, other than the first, in the timeline of this study. The term "index" in this explanation merely refers to the last of the paired events, not the first case initiating an epidemic. Index events included both completions and attempts as a result of our theoretical construct of a hypothetical contagion effect. The *case-*

event date at Unit X in expression 2 represents the date on which each control was randomly drawn from the USAF population.

Confidentiality

Individual names and social security numbers from the merged Casualty-AFMR dataset were deleted after we compiled case series rosters for Series A and Series B which we forwarded to AMSA. AMSA used these unique identifiers for records linkage as discussed above. The research dataset was created according to the investigators' statement of work and delivered to the investigators without the identifying information. AMSA assigned their own unique identifier to the subjects, securely maintaining the "key" to their identification system which would link back to the original identifiers. This preservation of confidentiality had one unintended consequence: we could not link back to our Casualty-AFMR data file for the case-control study. Thus death-related information on the suicide and suspected suicide case series was unavailable for study. This programming oversight did not stifle our hypothesis testing or prediction objectives, but it did cause some minor limitations in pursuing a deeper explanation for some of our findings.

Analytical Plan

Overview

Each study incorporates a different analytical approach. For Chapters 3 and 4, we performed exploratory data analysis, exploring relationships between the variables of study and the potential confounders, particularly whether the relationships were linear or non-linear. We also looked for evidence of collinearity using various techniques such as scatterplots and variance inflation tests in multivariate models. We assessed the potential for statistical interaction by stratifying many of these tables by another independent variable of relevance to our study questions. Prior to all-exposures multivariate modeling, we sequentially placed one exposure variable into a regression model (Poisson in Chapter 3, logistic in Chapter 4)

containing the complete field of extraneous variables to screen for confounding, using the *change-in-estimate* method with a specified cutoff for "significance". We used both forward and backward step-wise procedures to assess the estimate change by adding or subtracting one term at a time. Each study chapter lists the cutoff values that we chose for "confounder" status. We retained confounders (as well as interacting variables) for all subsequent multivariate analyses in which we focused on finding risk factors or protective factors for suicidal activity. All of the extraneous variables in our dataset were found to confound at least one relationship between a dependent variable and an exposure variable of primary interest. Some were later removed from multivariate models after finding them either to be collinear with other confounders or of insignificance to the multivariate model containing all of the risk/protective factors of interest.

The only exploratory data analysis necessary for Chapter 2 pertained to quality control. Before removal of unique identifiers, we checked for duplicate records and missing information. We also analyzed frequency distributions of our Casualty-based E codes for invalid codes.

We proceeded in Chapters 3 and 4 from bivariate and stratified analyses to multivariate analyses to assess the independent (or direct) effects of each covariate. Post-estimation assessment of each model's fit to the original data was performed using methods developed by Hosmer & Lemeshow (1989). In our case-control study, we assessed our risk factor models for their predictive ability, using developmental and validation samples from the same group of subjects.

ANALYTICAL PLAN FOR CASE-CONTROL STUDY (CHAPTER 4)

Preliminary analyses explored fundamental relationships between dependent and independent variables, particularly the extent of collinearity between the variables, using correlation matrixes during model construction. We also assessed all extraneous variables for confounding properties in forward and backward step-wise fashion. Certain variables were assessed for effect-measure modification (Rothman and Greenland 1998) if we considered their

potentially-modifying effects to be relevant to our study. Throughout all levels of analysis we looked for “dose-response” effects and non-linear patterns.

We performed bivariate analyses using all three outcome (dependent) variables to produce three tables of crude statistical associations. We then adjusted the associations by the full set of non-collinear extraneous variables using multivariate logistic regression. From these three “risk profiles” we assessed the potential for combining two or all three dependent variables into a single binary outcome, and to exclude any group from further analysis. Our strategy was that each series should either “blend in” with the risk profile of another series or should be distinctly different, provided the statistical relations were unequivocal on the direction of the association. We decided to exclude any of the three case series from analysis if point estimates consistently hovered close to unity and the 95% confidence intervals were equally equivocal.

Analysis proceeded to a third sequence: building separate multivariate risk factor models to distinguish between completers and attempters to test hypotheses on the independent effects of each primary factor of interest. From these models, we generated estimated probabilities of the event represented by the dependent variable. We then assessed our multivariate models for their predictive capability and fit to the actual data. We randomly split each of the two remaining case-control series into developmental and validation samples on which to test our predictive models. We fit our models on the developmental sample, then applied the results to the validation sample and assessed the goodness of fit.

Multivariate models were designed for two purposes: to ascertain independent risk factors and to predict suicidal events. Given the dual purpose, we attempted to strike a balance between the parsimony of risk factor modeling and the all-inclusive nature of prediction models. Our prediction models are intended to be used “in the field” where data processing capabilities may be limited, thus we limited the number of terms in the models to only those which were efficient contributors to the predictions. These “efficient” terms, as a result of this efficiency, were those which also qualified as independent risk factors. As an example our suicide model predicted 60 true suicides using nine terms which generated 98 unique covariate patterns.

Using 43 terms (including dummy variables) with 6,977 covariate patterns predicted only three additional suicides out of the 502 that were committed throughout the USAF during the study period.

Statistical Analysis: Theoretical and Conceptual Issues

Each of the three studies used different analytical techniques for describing the data or to test specified hypotheses, as may be seen in Table 1. These methods are more briefly covered in each of the chapters; however, the theoretical and conceptual basis for our statistical methods is only discussed in this section.

Chapter 2 Analytical Methods

The commonly-used kappa statistic was used to summarize the degree of agreement between the two different methods of, and reasons for, coding death certificate information. Death certificates were the seminal data source for both the AFMR and Casualty information systems regardless of their differences. The kappa statistic summarizes the relation between the observed agreement and the agreement which was expected by chance alone (Stata Corporation 1999). The kappa statistic was computed with Stata statistical software version 6.0 (StataCorp 1999), using methods by Cohen (Cohen J. 1968) and coefficient interpretation guidelines developed by Landis and Koch (Landis J. R. and Koch G. G. 1977).

Agreement was assessed from both qualitative and "traditional" perspectives in which we compared actual numeric ICD codes at various levels of coding precision. Agreement in the qualitative sense would indicate that the underlying cause ICD code that we derived from Casualty/DD1300 was as informative for epidemiologic research as those codes determined by AFMR nosologists, but not necessarily having the same ICD code. Lack of agreement would best conceptualized in this study as representing the differences between the two data sources in the information available on each death: Casualty and its administrative summary of death certificate information versus AFMR's full use of death certificate information (multiple-cause coding). Given the differences in data collection and coding methods used between the two

systems, we anticipated that the AFMR would be the "gold standard". However, we did not know to what degree, if any, that Casualty offices use internal investigation reports to correct or override the officially certified cause of death. If they used internal reports, we expected that the DD1300s would contain more specific and valid information than AFMR's ICD codes from death certificates. We found evidence both for and against their use of those reports. We also found that the AFMR's data quality was overwhelmingly superior to Casualty's. Having verified that AFMR was, indeed, the "gold standard", we supplemented kappa scores with measures of validity: sensitivity, specificity, accuracy, and positive predictive value when comparing the actual ICD-9 codes.

We created five qualitative categories on which paired ICD codes were first compared: precise, imprecise, nonspecific, discordant on illness versus injury, and missing from dataset (but listed in the other). More details on these methods may be seen in Chapter 4. Both weighted and unweighted methods (Stata Corporation 1999) (Szklo and Nieto 1999) were used for this analysis. Unweighted kappa was based on an exact (yes, no; 1, 0) match on the qualitative categories, but for weighted kappa we assigned weights based on the seriousness of the disagreement. A score of 1.0 was given for each death in which both data sets had the same level of coding precision. A weight of 0.85 was assigned when there was a difference of one ordinal category (e.g., AFMR = precise, Casualty = imprecise). A two-level difference (e.g., AFMR = precise, Casualty = nonspecific) was weighted 0.4. A three-level difference (e.g., AFMR = precise, Casualty = illness or unknown) was given a weight of 0.2. No "credit" was given (i.e., weight = 0) when we found a "non-death" in either data source, regardless of the ordinal difference. None of our kappa methods take "true negatives" into account, as non-deaths are obviously not recorded in either death registry.

Following the qualitative analysis, we assessed the level of exact agreement on the coding itself at all levels of coding specificity. The coding levels are as follows: manner of death (intent category) such as illness, unintentional injury, or suicide; broad cause group (e.g., E880–E888 for falls or jumps); three-digit (e.g., E955 for gun-related suicides); and, four-digit (e.g.,

E955.0, handgun-related suicides). Only unweighted kappa was used in this analysis since the ICD coding system is not completely ordinal. Thus, "close" in a numeric sense would not always indicate closeness in the cause of death.

CHAPTER 3 ANALYTICAL METHODS

Data Conformity to Poisson Assumptions

Poisson regression was chosen as the appropriate multivariate modeling method for the descriptive element's rate-based analysis of mortality. This method is best suited for the data, given how the data was "naturally" generated. The underlying processes of how the mortality data was generated gives insight to whether or not our data may be described by a Poisson distribution. Data are considered to conform to a Poisson distribution if four assumptions (Daniel 1991) are met, in no particular order.

The first assumption is that the occurrences of the events are independent, i.e., the occurrence of an event in a time interval has no effect on the probability of a subsequent event in the same, or any other, interval. Our study data is generally assumed to conform to this assumption, although catastrophic injurious events and suicides may violate the assumption to varying degrees. These types of injury deaths will be examined separately.

A second assumption is that the probability of observing a single event over a small interval is approximately proportional to the size of that interval, and as long as the interval size remains constant, the probability does not change over time. Suicide rates fluctuated over the study period, but only in 1998 was the rate significantly different (lower) than in the other years of the study. As a result, we were willing to accept that this criterion was met.

A third assumption is that, in any infinitesimally small portion of the interval, the probability of more than one occurrence of the event is negligible. Given the low density of suicide in the active duty USAF, our data appear to maintain that assumption.

The final assumption is that, in theory, an infinite number of occurrences of the event must be possible in the interval. No reasons exist for rejecting this assumption on any

theoretical grounds. The USAF mortality data, producing events/counts widely dispersed over calendar time, reasonably meets Poisson assumptions.

Bivariate and Stratified Multivariable Analyses

Mortality rate ratios and rate differences in Chapter 3 were calculated on the categorical variables (e.g., males vs females, officers vs enlisted) on each specific manner and cause (means) of death. These statistical relations were stratified by the other socio-demographic variables in our data (race, age, rank, occupation). Rate *differences* per *k* (usually 100,000 servicemember years) between different levels, or strata, of covariates were derived from rate ratios, allowing the investigators to assess statistical interaction on an additive scale, calculating attributable risk and assessing the joint effects in conventional 2X2 tables. Tests of significance of any additive effects were performed in Poisson regression equations, using an additive model variable coding scheme. Multiplicative statistical interaction between was formally assessed in stratified analysis using a Mantel-Haenszel (M-H) test of homogeneity (Stata Corporation, 1999) based on the χ^2 distribution of probabilities. An *a priori* decision was made to report separate effect measures (risk ratios) if evidence of heterogeneity presented, i.e., if the $\chi^2_{M\text{-}H}$ probability was 0.05 or lower; and, to further incorporate any interacting variable in a multivariate Poisson regression model as one component of a two- or three-component term. Various categorical classification and variable coding schemes were used during bivariate analyses to examine the exposure variables for non-linear or a non-ordinal effects on mortality rates.

Poisson Regression Multivariate Descriptive Analysis

Regression modeling, based on the Poisson distribution, is a frequently-used method to assess summary data consisting of rare event counts and their associated rates. Counts or rates are a function of exposure, spatial, time-period, demographic and other variables. (Rothman and Greenland 1998) Allowing r_j to represent the incidence rate for the jth observation, the logarithm of the incidence rate can be modeled as a linear function of one or more predictor (x) variables in the following manner:

$$ln(\lambda_j/E) = ln(exposure) + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_k x_k \ , \quad (3)$$

where λ_j represents the expected value of the count at a given covariate pattern and E_j is the exposure associated with that count expressed in person-years. Thus, the mean rate (r_j) for that covariate pattern may be calculated by

$$e^{\beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_k x_k} \qquad (4)$$

Assuming that a Poisson process underlies injury-related deaths, Poisson regression iteratively finds maximum-likelihood estimates of the parameters (Hamilton 1998). Poisson models, as described mathematically above, assume additivity on the multiplicative scale, i.e., no statistical interaction (Breslow and Day 1980b).

The x variables used to assign death counts in our models were year of death, age (category) at death, sex, race, rank category, and occupation. Of these six variables, we generally restricted our models to no more than four in any model due to progressively sparse data (few to no events in several cells) and small person-year contributions, leading to low statistical power and unstable rates over time. Each model's exposure, or linear offset, variable was comprised of person-years, producing mortality rate ratios as transformed coefficients for each β_K.

Assessment of, and control for, over- or under-dispersion of the data were conducted using generalized linear modeling (GLM). Dispersion problems exist when the variance of the covariate pattern-specific counts is higher or lower than the Poisson variance which is equal to the mean within-pattern count (Hamilton 1998; Rothman and Greenland 1998). GLM offers techniques to correct the standard errors that stem from this problem (Hamilton 1998; Stata Corporation 1999).

Full (saturated) models included all possible (two-way and three-way) combinations of terms which were assessed for statistical interaction, i.e., Poisson models which allowed multiplicative relationships between covariates. The decision on retaining or removing an interaction term was based on an assessment on each term's contribution to the model. The significance of interaction terms was based on the likelihood ratio test (LRT),

$$LRT = -2 \log (L_0/L_1) = -2 (\log L_0 - \log L_1) = \chi^2 \qquad (5)$$

where L_0 represents the log likelihood of the full model consisting of the main effects terms and the interaction term(s), and L_1 representing the log likelihood of a constrained model with main effects terms only (Rothman and Greenland 1998). While the log likelihood does not have a well-defined distribution, the *differences* in log likelihoods for different models may be interpreted as χ^2 values. (Breslow and Day 1980a) The test statistic is compared to a χ^2 probability with $(d_0\text{-}d_1)$ degrees of freedom where d_0 and d_1 are the model degrees of freedom associated with the full and constrained models (Stata Corporation 1999). This method is applied generally to Chapter 3's Poisson regression models for comparing nested (reduced or constrained) models to full models, with or without interaction terms. Each Poisson model was assessed for goodness of fit using χ^2 test output. All such models used to predict rates and rate ratios provided good fit to the raw data and contraindicated the need for additional variables.

CHAPTER 4: MULTIPLE LOGISTIC REGRESSION MODELING

Unconditional multiple logistic regression was selected as the primary modeling technique in the case-control study. The coefficients (after exponentiation) yield a measure of the strength of the association between our binary dependent variables (suicide, potential suicide, and attempted suicide)—the odds ratio—and we can use the non-transformed coefficients (logits) to derive an event probability. Given that the goals of the study were to ascertain (para)suicidal risk factors and assess the ability of those risk factors to predict an event, logistic regression was more appropriate than other methods such as discriminant analysis which could give impossible (i.e., greater than 1.0) event probabilities (Szklo and Nieto 1999). Our use of logits constrains those probabilities to a range of 0 to 1, a desirable feature. We also felt that the event probability of any of the three outcomes (dependent variables) conformed to a logistical model, and our post-estimation assessment of model fit largely confirmed that conformity. Logistic regression models assume that the relation between a variable (x) and the probability of an event (caseness) follows a logistic function (Szklo and Nieto 1999):

$$P(y|x) = 1/\{1 + exp[- (b_0 + b_1x_1 + . . . + b_px_p)]\}, \tag{6}$$

where $P(y|x)$ is the probability of an event (y) for a specified value for a covariate (x).

Conditional vs Unconditional Methods

Our study design and sampling method did not individually match subjects on any socio-demographic characteristic, thus *unconditional* logistic regression was justifiable. However, each subject's probability of caseness given exposure depended to some extent on their length of observation within the study. We created an observation time variable and conditioned our logistic models on it to evaluate any disparity between conditional and unconditional coefficients and standard errors. Differences between the conditional and unconditional models were negligible, and we continued to use and report only the unconditional methods.

The resulting coefficients from unconditional logistic regression worked better for the intended practical application of our attempter prediction model than those from conditional models. When used in practice at various military locations, the unconditional model results will allow prevention planners to plug their own observation time into the prediction equation. Statistical models conditioned on observation time would not allow this convenience. A common practice at military facilities is for investigators to request short-term (one year or less) personnel and hospitalization data, so most subjects will have been observed for a uniform time period. While our suicide attempt prediction model are valid for all possible observation periods from 0–9 years, we held the adjusted estimates of the odds ratios constant at the baseline value (less than one full year) which we believe will be the most commonly-used period of observation.

Observation Time Influence

Our study spanned nine years, and individual exposure information included only those within-period exposure events which occurred before subjects' date of death (for cases) or

selection as a control on the cases' date of death. In other words, no exposure could occur before January 1, 1990. Preliminary analyses indicated that, in the attempter series, "survival" in our study is synonymous with longer observation periods, but observation time is not collinear with any of the other predictors of survival. Our sampling of cases and controls did not preclude the possibility that a person with a short observation period in our study could have served in the USAF for a long period, but it is impossible for a person with an extended observation period to have only been in the military for a short period. Thus, shorter observation time is to some extent a proxy for youth and low rank, and negatively correlated with survival (or, positively correlated with attempting suicide). Our study in Chapter 4 eventually indicated that, as we had anticipated, young age (17–19 years) or being in the most junior rank category (E1–E4) are each a risk factor for attempting suicide. Our preliminary analysis for Chapter 4 using linear regression indicated that age increased by 1.4 years—and rank increased by nearly one-half of a grade level—for each additional year of observation. Observation time is obviously correlated with these two variables, but obviously not to the extent that we could appropriately dispose of that term due to collinearity. As a result of this exploratory data analysis, we included observation time as a term in our modeling of attempts.

Crude and Adjusted Odds Ratios

Logistic regression was used to adjust the crude estimates for the wide array of demographic, or extraneous, factors in the study. In preliminary analyses, we had used a *change-in-estimate* threshold of five percent to establish that a variable was, in fact, a confounder. Each extraneous variable in our study was identified as a confounder in least one of the crude associations between exposure variables and (para)suicide. None of the variables used in the adjustment were collinear.

Multivariate Model-Building

Backward step-wise logistical regression was used to eliminate "low potential" covariates for each of the two (completer and attempter) multivariate models, using an alpha

probability cutoff of 0.20. Further model reduction was done through deviance likelihood ratio testing of each of the remaining terms, using a Chi-square probability of 0.05 as a threshold for a covariate being "significant to the model", thus remaining in that model.

Generalized estimating equations (GEE) were used to derive OR estimates for the variable *time since exposure* (to a suicidal event), as the time it took to observe the first event in our study period was correlated with how long it took to see a second event, and so on. This was the result of differing population sizes at each Air Force base or major unit (i.e., those with separate zip codes). Suicidal activity is a rare event in statistical terms, thus much time would pass before many small units or bases would experience the first event during the study period. Likewise, *subsequent* events would also be spaced relatively widely apart. Larger bases and units, with larger denominators, would more likely experience events spaced more closely in time (i.e., greater incidence density). In statistical terms, the serial measurements of the time distances between events within each unit, or at each base, were not independent of one another. GEE methods allowed the effect of the exposure to vary randomly by base/unit, consequently we refer to these as random effects models. These random effects are reported as aggregate, or population-averaged, odds ratios.

Assessment of Model Fit

Post-estimation assessment of the models' fit to the actual data was conducted using methods given by Hosmer and Lemeshow (1989). The two final models were assessed for the predictive capability using consensus methods (Hosmer and Lemeshow 1989; Stata Corporation 1999) which advocate using developmental and validation samples from the same dataset.

Linear Trends (Dose-Response)

Variables constructed with multiple levels of "exposure" were assessed for a "dose-response" statistical relation. Two types of tests of linear trend were used in the analyses, Mantel's trend test (Rothman & Greenland, 1998; Szklo & Nieto, 2000) and a multivariate

ordinal trend test (Rothman & Greenland, 1998; Szklo & Nieto, 2000), depending on the linear model's fit to the data. We were attentive to the need to keep residual confounding to a minimum in this exploratory study. Our categorization of quantitative variables (number of hospitalizations, age, rank, years of service) was based on the trends or patterns in the ORs prior to variable reduction to categories or dichotomy. We strove to maintain within-category OR homogeneity and between-category OR heterogeneity in our analysis. Another criterion for determining categorical cut-points was the consistency of the linear effect (OR increase or decrease) produced by a one-unit change in the quantitative independent variable.

Missing Data

The method in which we constructed the variable *time since exposure* (refer to Chapter 4 for a detailed methodology) precluded assignment of values for observations which were either "first events" or "first sampled" (for controls) at each base, as there were no index observations prior to the starting period for this study. In other words, we could not calculate a real *time since exposure* until after a base experienced its first suicidal event. In several instances, a string of controls was sampled prior to a first event. Neither those controls nor the first-in-study base-level suicidal events were given a value for *time since exposure.* These missing values (n = 112) were the only missing data in this study. For prediction modeling, these observations were assigned imputed values for *time since exposure* based on the median value for the case-control series (e.g., attempter or completer) given that the observation was either a case or control. Otherwise, 112 observations contributing other information needed to predict these events would have been excluded from the models.

Statistical Power

This case-control study had statistical power of 55 percent in the completer case-control series to detect a statistically significant (Type I error probability = 0.05) odds ratio of 2.0 when the exposed proportions were 0.15 in cases and 0.075 in controls. These exposure proportions represent "middle ground" for our variables of interest. In the attempter series, the power to

detect the same significant risk difference was 95 percent. We practically had no power (3 percent) to detect an odds ratio of 2.0 in completers for the various types of mental health hospitalization exposures (e.g., alcohol-related, depression) in which the exposed proportions of both cases and controls were below five percent, while the detection power in attempters was nearly 30 percent. Fortunately, the resulting odds ratios were large, and we had sufficient power to detect those strong associations. Statistical power in the "potential suicide" series was far lower, but the larger problem was our apparent misspecification of the case series, a validity issue. Our definition of suspected suicides (discussed above) produced a "flat" risk profile in general. Risk estimates were often so close to the null that even the power we had for attempters would have been insufficient to detect a statistically significant difference.

Summary

The purpose of this research is to investigate risk factors for suicides and attempted suicides in the U.S. Air Force, and to assess risk factor models for their ability to predict these events in individuals, or in groups of individuals with the same risk factor-sociodemographic profile. We developed a more valid method for developing and describing a suicide case series than had been used in past military studies. Our studies used data sources that had rarely been used previously. The Air Force Mortality Registry provided improved information on the external cause of injury-related deaths, allowing us to explore potentially misclassified suicides and to examine various suicidal mechanisms. The epidemiologic methods we used for the case-control study allowed efficient statistical examination of several potential risk factors for suicide and suicide attempts, using population-based (but individual-level) data sources. Our methods are also "field-expedient". The risk factors/predictors in Chapters 3 and 4 originate from corporate USAF databases, thus our methods may be replicated relatively easily throughout the USAF without the need for primary data collection. We believe our application of these more rigorous methods and valid sources of data will set a higher standard for subsequent military research in this area.

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CHAPTER 2

Comparison of the Level of Agreement Between Two Sources of U.S. Air Force Injury Mortality Data

Abstract

This study assesses the level of agreement between two sources of USAF mortality data for the period 1990–1998. The two data sources were the often-used DoD Casualty data, consisting of administratively-coded manner of death and Report of Casualty (DD Form 1300) information, and the "gold standard" Air Force Mortality Registry (AFMR). The investigators used the information from the two-part Casualty data to derive E codes for each injury death. The AFMR features multiple-cause mortality coding (including E codes) by trained nosologists, directly from official death certificates. Qualitative analysis found that sixty-five percent of AFMR E codes were "precise" compared to Casualty's 34 percent; AFMR listed nonspecific E codes for one percent (13 deaths), while 6 percent (95 deaths) of Casualty's E codes were nonspecific. Sixty-four "unspecified accident" E codes from Casualty were "reclassified" by AFMR into specific cause codes. The AFMR registered 8 additional injury-related deaths, and 33/1,610 (2%) of paired records listed a different manner of death. Substantial agreement (76 percent) was noted between the actual cause-group E codes (e.g., E800-E807). Exact three-digit E codes were in 73 percent agreement, but four-digit agreement dropped to 54 percent. The sensitivity of the Casualty-based E codes was inconsistent at the three- and four-digit coding level. Casualty's lack of cause-specific information is an unreliable surrogate for death certificate information, a critical deficiency for injury-related research and prevention planning.

Introduction

Good epidemiologic data on specific causes of injuries is essential to provide information to those who plan and implement injury interventions. Information collected on fatal injuries is generally more complete than that of non-fatal events which are often subject to underreporting. Investigation of deaths from unnatural causes in military personnel often involve additional inquiry, as both civilian and military agencies often have somewhat overlapping jurisdiction. Most recent military injury mortality research (Hansen and Jones 1996; Helmkamp and Kennedy 1996; Atlas of Injuries in the U.S. Armed Forces 1999; Hourani, Warrack and Cohen 1999) is based on the Worldwide Casualty System (WCS), or Casualty, information. This official source of Department of Defense (DoD) mortality information has significant limitations in the specific cause and circumstances on deaths which are detailed in those papers. Standard *multiple cause of death* vital statistics data, used by the National Center for Health Statistics (NCHS) for mortality surveillance and research on the general U.S. population, have been unavailable for the military. Casualty information does not offer multiple cause information, and it is not possible to completely ascertain military deaths in national databases (Helmkamp 1995b).

Casualty data comes from the DoD Form 1300 (DD1300), Report of Casualty, on which base-level personnel officials annotate the underlying cause of death from a copy of a deceased servicemember's official death certificate. The expressed purpose for the DD1300 is to pay benefits, collect casualty data, and close out active personnel files (Department of Defense 1991), not necessarily to provide epidemiological information. This information is not coded in any fashion, and is not electronically linked to the *manner of death* administrative code assigned by Casualty officials. Helmkamp used the DD1300 information to describe military suicides (Helmkamp, 1995a), homicides (Helmkamp, 1995b), and overall mortality (Helmkamp & Kennedy, 1996) beyond the WCS' administrative manner of death categories (illness, accident, self-inflicted, homicide, hostile fire, terrorist, undetermined). However, his classification scheme

for the actual causes of death was still limited to broad causes such as "motor vehicle accidents".

Official DoD policy does not recognize, or sanction, any source of death information other than the death certificate (Department of Defense 1991), such as the more detailed internal death investigations. While such detailed information is highly desirable, it is neither readily accessible nor "electronic". We believe that the more practical combination of Casualty's manner of death and DD1300 "cause of death" information may be used to acquire greater specificity on the external and underlying causes of death than has been previously published. This information might—in the absence of internal investigation reports and a DoD mortality surveillance system using all of the death certificate information—be a reliable surrogate for such more informative data.

The primary objective of this study is to compare fully-exploited Casualty/DD1300 information to that which is available from standard death certificates. The WCS information will be combined to derive *external cause of death International Classification of Diseases, Ninth Revision* (ICD-9 E codes) to assess the potential for using that information as a surrogate for an NCHS-like surveillance system for the military. From this point forward, we commonly refer to the combination of the electronic Casualty information, the DD1300 information, and investigator-derived E codes derived from this information simply as "Casualty" information.

This study introduces a newly-developed source of death certificate-based multiple-cause mortality information, the Air Force Mortality Registry (AFMR), to which Casualty data will be compared. The AFMR is compiled by a team of nosologists at an agency commonly referred to as "Ranch Hand" (RH), which runs an ongoing cohort study on the health effects of Agent Orange. The AFMR's level of information is comparable to that used for mortality surveillance and research on civilian populations. This death certificate-based data is used as the "gold standard" in most parts of this study.

The comparison between AFMR and Casualty data will be presented on three levels: qualitative coding specificity, incidence (mortality) by intent category (manner of death), and

coding agreement on both broad and specific underlying causes of death. The ultimate goal of this study is to investigate the best means of acquiring accurate ongoing mortality data in the military for injury surveillance, research, and prevention planning.

Methods

AFMR Construction

The AFMR, in its early stage of development, was comprised of USAF deaths which occurred in the period 1991–1998. RH routinely retrieves copies of standard death certificates from the vital statistics agency (or, more recently, directly from the Air Force bases) within the jurisdiction of decedents' place of death after having been notified of each active duty death by the USAF Casualty Affairs Office. A roster of USAF deaths is periodically run against updated Social Security Administration and Internal Revenue Service data tapes to locate and acquire death certificates which were not collected prospectively, as the AFMR continues to expand at both ends. RH employs nosologists trained on multiple-cause coding (i.e., underlying and contributory causes) at the NCHS who code all information available from the death certificates into ICD-9 format, including E codes, then use NCHS algorithms to derive a valid underlying or external cause of death. Underlying causes of death are determined independently of the underlying cause specified by the certifying authority. Retired servicemembers are tracked for 120 days after military discharge. The "120-day retiree" category includes both career retirees and individuals who were involuntarily and promptly retired due to serious illness or injury for which residual disability or death is expected. Deaths occurring after retirement would not be included in Casualty statistics even if the injury or illness occurred while on active duty. As a result of their omission from Casualty, these individuals are not included in this study since this is a side-by-side database comparison. It is important, however, to be aware of the 120-day retirees for further discussion.

The investigators subsequently classified AFMR E codes into categories of intent (unintentional injury, suicide, homicide, legal intervention, undetermined intent) according to the ICD-9 classification scheme, and classified N-codes as "illness" (ICD-9 001–796) or "unknown cause" (N797-N799). Casualty information (see below) was used to identify homicides which were related to acts of terrorism which, along with hostile fire-related deaths, were combined into a single category, terrorist/hostile.

Casualty Construction

In a parallel effort, a similar Casualty data set was created. The primary investigator derived ICD-9 E codes for the apparent underlying cause for all USAF injury-related deaths during 1990–1998. The basis for the E codes was the two-part Casualty information: the WCS administrative code for the intent category and the DD1300s text-based information. Casualty information was coded to the same level of specificity as the AFMR, or to the greatest level of coding precision that was achievable from the available information. Deaths in which the manner or underlying cause was ambiguous (e.g., "Illness: sudden respiratory failure of unknown etiology") were assigned an ICD-9 N code of 799.9 (ill-defined and unknown causes). Casualty's manner of death was accepted at face value and never altered. The Casualty files were incomplete for 1998, with only 68 deaths having been fully registered at the time our study began. We used these 68 deaths to increase the precision of analyses requiring paired data, but did not include those deaths for unpaired analyses below.

The primary investigator (GBC) is an experienced military epidemiologist with doctoral training in the area of injury epidemiology. Coding of difficult cases was done under consultation with the co-investigator (GSS), a widely-published injury epidemiologist with particular training and expertise in injury-cause classification systems. Neither investigator is a certified nosologist.

Both data sources use names and social security number as unique identifiers, and they were subsequently merged on the identifiers for analytical comparison. Five records did not link, and we found that each was missing from the Casualty data files. All records in the

Casualty files were successfully linked to AFMR records. Unique identifiers were removed once the linkage was established.

A nested dataset was created within the Casualty dataset in which the investigators assigned E codes solely on the basis of information contained within summaries of internal death investigations (forensic reports). This information was available on the subset of USAF female deaths, and was used in this study to determine the value of acquiring and including the forensic information to derive the external cause of death. These summaries were taken from of copies of electronic communications between USAF and WCS officials in which relevant findings were discussed. This information was acquired as part of another research effort, and was only available for female deaths from non-natural causes which warranted an internal investigation. This additional case information will hereafter be referred to as the "internal report".

Both Casualty and AFMR datasets contained Reservists and Air National Guard (ANG) members, but only the Casualty data contained a field to identify them. Non-Active Duty (NAD) were removed once they were identified as a result of the dataset linkage. Cases unique only to the AFMR (i.e., not Casualty listed) could, therefore, be NAD. That probability is, however, low since only six percent of the remainder of the cohort (those which appear in both databases) were NAD. Reservists and ANG, as opposed to Active Duty, are activated for a limited and generally brief period. They were excluded from this study since their death investigations may involve a different and less uniform set of procedures, particularly if the death occurred in the civilian environment such as would occur if these individuals were attending monthly (weekend) drill activities in proximity to their hometowns.

Qualitative Methods

For qualitative analysis of the specificity of the underlying cause coding, five levels, or categories, were created which reflected the degree of E-coding precision for injury-related mortality. The highest level, *precise*, was used to indicate deaths which had been coded to the

highest level of ICD-9 specificity achievable within the limitations of the coding scheme, generally at the fourth digit. The category of *imprecise* was used to indicate that a more specific E code was available for that particular underlying cause. This category was used for suicides by firearms or explosives which were coded as E955.9 (unspecified firearm or explosive) when a wide range of more specific firearm (E955.0-.3) or explosives (E955.5) codes are available. Had the ICD coding scheme not included a fourth digit, E955 would have been as precise of an E code as could be expected, e.g., assault by drowning (E964). Other examples of this category are non-specific drownings (E910.9), other and unspecified alcohol poisoning (E860.9), unspecified falls (E888.0), and in vehicle-related deaths in which the type of mishap (E819.X) or the role of the occupant (E819–E829 [.9]) were not specified. *Nonspecific* indicates that the E code failed to convey a specific means, or underlying cause, of death even though the manner (intent category) of death is specified. Examples of unspecified underlying cause E codes are E928.9 (intent category: unintentional injury), E958.9 (suicide), E968.9 (homicide), and E988.9 (undetermined intent). Two "discordance" categories were created, realizing the potential for deaths to be coded as an injury in one data source while being coded as illness or of unknown cause in the other, and the possibility that some deaths may be registered in one database but not in the other. Each of these possibilities would have a qualitative impact on the analysis. This study's *illness or unknown* category represents the former situation, while *missing* (not registered) represents the latter possibility.

E-Coding Agreement

ICD E codes, reflecting both the manner and underlying cause of death, were used to assess the reliability of the actual E coding. In other words, how well did E codes derived from Casualty information agree with E codes from the AFMR? E codes were compared at all levels of coding specificity, i.e., manner, cause category, three-digit, and four-digit.

Statistical Analysis

The qualitative analyses use a common reliability assessment technique in a non-standard way to compare the two sources of mortality data. The interrater agreement in the quality (specificity) of the dual-source data was examined using the kappa (κ) statistic which summarizes the relation between the observed qualitative agreement and the agreement which was expected by chance alone (Stata Corporation 1999). Both weighted and unweighted methods are used in this study depending on the type of analysis which was warranted. The kappa statistic and related output was computed with Stata statistical software version 6.0 (StataCorp 1999), using methods by Cohen (1968) and coefficient interpretation guidelines developed by Landis and Koch (1977). Agreement in the qualitative sense indicates that the investigators' Casualty-derived underlying cause ICD E code offered the same level of detail as AFMR E codes.

Weighted kappa methods (κ_{wgt}) were used in addition to non-weighted methods to examine the qualitative concordance, using the five ordered categories of coding precision above. Assigned weights were based on the seriousness of the disagreement. A score of 1.0 was achieved for each death in which both data sets had the same level of coding precision. A weight of 0.85 was assigned when there was a difference of one ordinal category (e.g., AFMR = precise, Casualty = imprecise). A two-level difference (e.g., AFMR = precise, Casualty = nonspecific) was weighted 0.4. A three-level difference (e.g., AFMR = precise, Casualty = illness or unknown) was given a weight of 0.2. No "credit" was given (i.e., weight = 0) when a death was noted in one data source but not the other, regardless of the ordinal difference. None of the kappa methods took "true negatives" into account, as non-deaths were obviously not recorded in either death registry. Non-weighted κ is based on an exact (yes, no; 1, 0) match on the qualitative categories or the actual ICD-9 coding. For qualitative analyses, no "gold standard" was assumed.

Different years are used in the analyses depending on the parameter being measured. Casualty data were complete through 1990–1997, but 1998 was incomplete at the time of the

study; AFMR data is complete from 1991–1998, but was not available for 1990. We used all the available deaths encompassing all years for analyses not requiring paired data (i.e., when analyzing the data sources individually). Incidence was compared only for those years for which both data sources are complete, 1991–1997, a situation requiring paired data.

Analyses of the actual differences in paired death E codes necessitated calculation of sensitivity and specificity, as the AFMR was held as the "gold standard" based on its superior qualitative results. Only the non-weighted kappa method was used at this level of analysis, as the ICD coding scheme is not completely ordinal. Normally, missing records would be excluded by such a paired data method, but the *missing* category represented the lowest order ("least precise") of coding.

Results

Qualitative Comparison

The AFMR coding was qualitatively superior to Casualty codes for all manners of death except terrorism/KIA, for which the two data sources have nearly the same level of coding precision (Table 1). AFMR data did not include calendar year 1990, and Casualty data were incomplete for 1998; thus, their totals differ. The percentages of precise and imprecise codes showed opposite patterns. Six percent ($n = 95$) of Casualty deaths were assigned *nonspecific* codes compared to the AFMR's one percent ($n = 13$) for the same. There were 18 deaths in which the AFMR codes indicated injury where Casualty information indicated the death was from natural or unknown causes. Seven of these cases were classified as "unknown" due to long-standing (1997 and earlier) administrative intent category codes of "pending". The distribution of these discordant classifications are discussed below and shown in Table 4. Five deaths from the AFMR data were not listed in the Casualty files. We noted several DD1300s for injury-related deaths on which the "Cause and Circumstances" section was annotated with information not considered as valid underlying/external causes, e.g., "[intent category:] multiple

blunt trauma". These were E-coded as unspecified codes within their appropriate intent category. This inability to capture a valid underlying cause of death contributed significantly to the comparatively low specificity of our E codes of Casualty information.

A total of 397 injury-related deaths received qualitatively better underlying cause codes in AFMR compared to those derived from Casualty information (Table 2). Another 15 deaths considered either as non-injury or "missing" in Casualty received external causes of death in the AFMR. The diagonal line indicates the axis of qualitative agreement receiving weights of 1.0 in the weighted kappa analysis. There were 58 precisely coded injury-related deaths in AFMR for which Casualty information conveyed only non-specific E codes. In the non-weighted analysis, exact qualitative agreement was fair to low-moderate. The agreement was poorer (fair) in the weighted analysis in which closeness in the coding specificity was rewarded, and where the expected level of agreement was higher.

Casualty-derived E codes were superior in 11 deaths (i.e., those below the diagonal). The investigators coded two AFMR-listed "unspecified falls" (E888.0) each as "fall from one level to another" (E884.9) based on information on the DD1300s. Two AFMR homicides coded as "unspecified means" (E968.9) were coded by the investigators as "striking by blunt or thrown object" (E968.2). The AFMR coded one Casualty motor vehicle mishap (E819.9) as "accident, unspecified means" (E928.9). The other six more precise Casualty-based E codes were the result of "other specified means" being coded in the AFMR as "unspecified means", and Casualty-based injuries (one firearm-related suicide, one accidental fall, and one accidental poisoning) being coded as illnesses in the AFMR. The actual N codes in AFMR for those illnesses may have been of equal or greater precision as the investigators' E codes, but they were considered as qualitatively inferior for the purposes of this study which focuses on injury.

Mortality Incidence Comparison

The proportionate mortality (i.e., the manner-specific percentages) was nearly identical between the two data sources (Table 3); however, the differences are noteworthy. The data

cover the period 1991–1997, the years in which both data sources offer complete information on which a fair comparison on the number of incident cases (deaths) could be made. The AFMR listed five more deaths than did the Casualty file, and Casualty excluded three suicides and two illness-related deaths listed in the AFMR files. Even when the data agree that a death occurred, there was some disagreement on the manner of death. The AFMR listed eight more unintentional injury deaths than did Casualty. The other intent categories agree more closely after accounting for the "missing", but only deaths from hostile fire/terrorism are in complete agreement. Casualty's administrative code of "Undetermined" differs from the ICD-9 intent category of *Injury Undetermined Whether Accidentally or Purposely Inflicted* (E980–E989). Casualty system's administrative coding includes not only injuries of questionable intent, but any death of unknown etiology (N797-N799).

ICD-9 Coding Agreement

AGREEMENT ON MANNER OF DEATH (INTENT CATEGORY)

Calendar year 1998 deaths were introduced into the analysis to assess the level of agreement (κ) on the *manner of death* classification of all deaths common to both data sources (n = 1,610 pairs) during the study period (Table 4). Casualty's manner of death classifications were generally concordant with those of the gold standard AFMR, as evidenced by $\kappa = 0.96$ (almost perfect agreement), as only 32 discordant manner of death classifications were found. The manner of death was considered as concordant when Casualty classified a death as "Undetermined" and the AFMR's codes placed those ambiguous deaths (n = 20) into either the "Undetermined Intent" category or the "Unknown" category.

Twenty "undetermined" deaths in Casualty were classified into a more appropriate (and generally more precise) intent category in the AFMR (Table 4). Eleven of these deaths were determined to be injuries of undetermined intent. Five were ill-defined/unknown deaths, three were illnesses, and one was an unintentional injury death. One of the intent categories, legal

intervention, is undefined by the Casualty information system, and the lone AFMR-coded death in this category was listed as a homicide by Casualty.

Deaths classified as illness in Casualty, but injury-related according to the "gold" AFMR, were the most frequent source of discordance at this level of coding. The AFMR's coding placed 9 of these 13 "invalid" classifications into the unintentional injury category, three into "Unknown", and one into the "Injuries of Undetermined Intent" classification (Table 4). The AFMR three- and four-digit E codes for the misclassified accidents (data not shown) indicate that the underlying causes of death were not "classic" accidents. Instead, they were due to drug poisonings (both therapeutic and non-therapeutic use), alcohol poisonings, medical misadventures, or suffocations due to inhaling or ingesting food or other substances. There was one exception, an electrical shock The AFMR listed illness-related contributing causes (N codes) for each of these manner-discordant deaths, a key finding that will be discussed below.

AGREEMENT ON INJURY BROAD CAUSE GROUPING *(EXXX – EXXX)*

Of the 1,610 deaths common to both data sources (Casualty "pending" excluded), 103 differed in their three-digit E code grouping, or underlying cause categorization (data not shown). The observed level of agreement (not shown) was 76 percent, compared to an expected level of agreement of 11 percent, $\kappa = 0.73$ (substantial agreement). E codes with different third digits, but still falling within an E code grouping, were not considered as discordant at this level of analysis. For instance, while the E860.0 (alcoholic beverage) and E866.9 (unspecified solid or liquid substance) codes differ at the level of the third digit, each is nested within the *Accidental Poisoning by Other (non-drug) Solid or Liquid Substances, Gases, and Vapors* (E860–E869) grouping; thus, these were considered concordant at that level.

The parameters of agreement on which κ is based were computed (data not shown) for the most common E code groupings of unintentional injury deaths—motor vehicle traffic (E810–E819), poisonings (E850–E869), falls (E880–E888), drownings (E830, E832, E910), and aircraft-related deaths (E840–E845). The sensitivity of the investigators' E coding of Casualty information was above 90 percent for each of these categories except for poisonings (sensitivity

= 76%) and falls (sensitivity = 50%). Specificity was consistently high, ranging from 96 percent to 100 percent. While 44 of the 45 gold standard "conventional" accidental drownings (E910) were detected in Casualty information, that information was insufficient to detect any of the four watercraft-related drownings (data not shown). Each had been coded by the investigators into the E910 range instead of the "gold" E830 (watercraft-associated) grouping. Likewise, the investigators coded four drownings from other causes (hurricanes and plane crashes) into the same E910 code. Typical DD1300 entries included the key words "drowning" or "submersion" but made no mention of a boating accident or other specific cause.

The most remarkable redistribution of discordant underlying causes at this level of categorical classification occurred in Casualty's *Unspecified Accident* grouping, actually two distinct E codes, E928.9 (accident of unspecified means) and E929.9 (late effects of the same) (Table 5). Nine different AFMR cause categories received those unspecified deaths, with 42 cases falling into the motor vehicle (MV) and roadway death category. For these AFMR reclassifications, the DD1300 was typically annotated as "Accident" with a description of the actual injury (e.g., "multiple blunt trauma to head"), generating the investigators' E928.9 coding decision. Ten Casualty-listed "Illness" deaths were assigned into injury-related E code categories by the AFMR nosologists. These discordant classifications were distributed rather randomly among the AFMR's non-transportation E code groupings, but Table 5 shows only those reclassifications for which AFMR considered as unintentional injuries. Manner-discordant deaths, obviously discordant at the E code group level as well, may be seen in Table 4.

Agreement on Three-Digit (EXXX) E codes

From this point forward, the results of the analyses pertain only to those 1,504 deaths that AFMR nosologists coded with an external cause, i.e., gold standard injury-related deaths, from 1991–1998. The array of three-digit E codes is too vast to provide meaningful numbers for assessing the parameters of coding agreement in 2 X 2 contingency tables for all three-digit codes.

The overall E coding agreement at the three-digit level was "substantial" ($\kappa = 0.73$); however, the investigators' codes showed mixed results in matching the underlying cause of death with that of the AFMR for the most frequently-used E codes (Table 6). The Casualty-based E codes failed to match even 70 percent of AFMR-listed suicides by cutting or piercing injuries, or pedestrians who were hit by motor vehicles. On the other hand, the Casualty information enabled the investigators to match 96 percent of the firearm-related suicides cited by the AFMR's codes. Specificity is not addressed in this analysis since that parameter approached 100 percent for all Casualty-based codes, given that most deaths fell outside any given three-digit code.

AGREEMENT ON FOUR-DIGIT (EXXX.X) E CODES

Of those 1,032 pairs which showed E-coding agreement at the three-digit level, 254 (25 percent) differed when the coding scheme was extended to the fourth digit. The overall level of agreement was poorer at the four-digit level, 57 percent, based on an expected agreement of six percent, $\kappa = 0.54$ (moderate agreement), data not shown. The ability of Casualty information to identify precise gold standard external causes (sensitivity) at this level followed a less consistent pattern than seen at the three-digit level (Table 6). For instance, while the sensitivity of investigator-derived E codes on deaths due to non-military, non-commercial air accidents (E841.5) was 100 percent (18/18), investigators' E codes failed to identify any of the 11 suicides in which the instrument was a hunting rifle. Suicides comprised 132 of the 254 coding disagreements, followed by 99 discordant codings for unintentional injuries and 17 for homicides (data not shown).

The most remarkable coding difference emerged from the *Suicide: Other and Unspecified Firearm* (E955.4) underlying cause derived from Casualty information, data not shown. The investigators assigned 85 suicides to E955.4, 77 for which the AFMR had coded into precise firearm codes: handguns (E955.0), 49 deaths; shotguns (E955.1), 19 deaths; hunting rifles (E955.2), 11 deaths; and military firearms (E955.3), 1 death. The low sensitivity in identifying the precise firearm from Casualty-derived codes persisted into the homicide

category, as only two of 12 AFMR handgun-related deaths received E-codes of the same, sensitivity = 17 percent.

Generally, fourth-digit discordance for unintentional injury deaths occurred relatively evenly among the wide array of available cause-specific E codes (data not shown). The most notable coding differences in this intent category were in the *Motor Vehicle Accident of Unspecified Nature, Unspecified Person* (E819.9) code for which the AFMR E codes were able to specify the person (e.g., driver, passenger, pedestrian, etc.) in 21 of those deaths. The same number (21) of unspecified drowning deaths (according to the investigators' codes) were E-coded in AFMR with more informative fourth digits.

Another E-code sensitivity problem was found when consolidating all of the numerous four-digit codes in which motorcycle operators or pedestrians are specified by the last digit. Casualty-based E codes missed 15 of 56 motorcycle operator deaths (sensitivity = 73 percent), and 7 of the 17 pedestrian deaths (sensitivity = 59 percent), data not shown.

Three-way Comparison of Female Injury-Related Deaths

The internal information contradicted the manner of death in both primary data sources for two of the 27 female deaths (Table 7). One Casualty-listed suicide was, according to the internal report, an unintentional injury, and a Casualty/AFMR homicide was actually determined by the investigation to be suicide. The narrative of the latter case investigation clearly indicated that the gunshot was self-inflicted, but the official WCS affirmed the official cause of death as listed on the death certificate (homicide), which was also taken at face value by the AFMR nosologists. That death occurred in Great Britain, and a suicide note—required in that country for a non-witnessed death to be ruled as a suicide—was not written. Casualty officials were bound to honor the sovereignty of the official determination of cause despite information to the contrary.

When the manner of death was consistent across the three information systems, the contradictions on the precise external cause of death were generally unremarkable. The internal report's information frequently revealed a more precise cause of death, or offered information

which moved E codes to (or from) "unspecified" codes to (or from) "other specified" codes. However, in two instances the situation was reversed: AFMR and Casualty information disclosed a precise type of firearm while the internal report information indicated "unspecified firearm".

Casualty and AFMR codes agreed substantially on the exact cause of death, but the agreement between either of those two databases and the internal report information was only fair to moderate (Table 7). In other words, our two primary data sources were in closer agreement than each was with the internal report information.

Discussion

Lack of agreement is best conceptualized in this study as representing the differences between the two primary data sources in the information available on each death: Casualty and its administrative summary of death certificate information versus AFMR's full use of death certificate information. Actual differences in coding decisions probably occurred between the investigators and RH nosologists, but these inconsistencies were probably not qualitative. In other words, the investigators may have coded a particular death differently from AFMR's coders, but the misclassification would have been of the same level of specificity as the nosologists' code, assuming similar descriptive information on each death.

Qualitative Comparison

There are significant qualitative differences between the two sources of mortality data. Generally, the AFMR's E codes have twice the precision of the E codes we were able to derive from the two-part Casualty information. Differences in the coding precision were, however, not unexpected given the different information needs between Casualty's administrative requirements and AFMR's sole reason for existence, epidemiologic research. The injury epidemiologist's plague of non-specific E codes was six times more frequent in Casualty-based codes than in the AFMR's coding. The qualitative difference represents the magnitude of the

information loss when death certificate multiple cause information is abstracted onto DD1300s by WCS personnel who are not trained in nosology. No compelling reason exists for WCS to spend additional resources to improve the precision of the information since the information they collect and their coding scheme is sufficiently precise for their operational needs. However, the obvious end result is that valuable death certificate information is lost; however that value is only realized by epidemiologists and policymakers.

Our choice of the AFMR as the “gold standard” is clearly justified by the finding that the Casualty information on over 400 theoretically preventable deaths is less precise than what was available directly from the death certificates. Death certificates themselves provide only the most basic mortality information, thus the gap between the desired level of information and the information available from Casualty is extensive. The kappa statistic provides a concise method of summarizing the level of agreement between data sources, but fails to convey the full impact of the non-agreement. Despite moderate (67%) qualitative agreement, the remaining one-third of paired deaths were overwhelmingly situations in which the AFMR had the more precise information. This finding suggests that the Casualty system is an unreliable source of detailed death certificate information. The 11 deaths for which Casualty information was superior indicated that, despite official instructions to the contrary, the DD1300 may have occasionally been annotated with additional information beyond what was available from death certificates. This issue will be explored further below.

Incidence Comparison

Tables 3 and 4 each show different numbers of deaths in each intent category, with potential explanations discussed in following sections. There is no certain explanation for the “missing” deaths in Casualty. This finding was unexpected given the seriousness and certainty associated with death, and that the “starting place” for both the AFMR and Casualty information systems is the Air Force Personnel Center. We only compared incidence for those years in which both data sources were complete. We also used Casualty to exclude NAD deaths, so

both data sources should have included the same group of deaths. One possible explanation is the AFMR's inclusion of 120-day retiree deaths. We excluded those deaths which were identified as such from the analysis, but it is possible (albeit unlikely) that the Ranch Hand data entry personnel failed to identify all 120-day retirees in their coding, and they appeared as Active Duty deaths. Another unlikely scenario is that surviving family members/beneficiaries elected not to "register" the death by completing a DD1300. Further study, using other data sources, will be needed to produce a definite reason for the lack of agreement.

Coding Agreement

Manner of Death

Casualty data is a suitable, if imperfect, surrogate for death certificate data at the intent category (manner of death) level of classification despite the missing deaths discussed above. Disagreements in the manner of death are perplexing since both agencies' data ostensibly came from the same field of death certificates. The manner of death is clearly indicated within a box on the death certificate where a manner of death is chosen by the attending physician or medical examiner/coroner. The most likely explanation for deviance on the manner of death is that the AFMR nosologists use of NCHS multiple-cause algorithms resulted in technical corrections of the certifying authority's decision on the manner of death.

The explanation above is most applicable in those deaths that the AFMR codes reflected unintentional injury, but were administratively coded in Casualty as an illness. We noted several unintentional injury deaths in which the *underlying cause* could more likely be misclassified as an illness by WCS officials. These discordant manner of death cases were (according to the AFMR) caused by drug poisonings, medical misadventures, and airway obstructions leading to suffocation, except for a single electrocution. All received N codes for *contributory* cause(s) on their death certificate, according to the AFMR. A juxaposition of the underlying and contributing cause(s) of death by the physician or other official completing the death certificate could have produced an "incorrect" manner of death within the Casualty

reporting system. A Casualty technician viewing a death certificate would most likely look for the underlying cause in its customary place, and unwittingly type whatever information was in that place onto the DD1300. For example, Casualty classified two medical misadventures (both surgical procedures) as "illness", as were probably indicated on the certificates. The AFMR coded both of these cases with *disease of the circulatory system* (N390–N459) listed as a contributory (not underlying) cause. The true (AFMR) underlying cause of death in both cases was the surgery-related error (misadventure), and the death certificates should have indicated likewise, with an attendant "unintentional injury" classification noted in the check box. The certifying physician likely confused the contributing cause (the illness, e.g., coronary heart disease) with the underlying cause (the misadventure), and checked the incorrect "illness" box. Ranch Hand coders are trained nosologists and, unlike Casualty coders, would have recognized the invalid underlying causes of death on the death certificate, and replaced them with the true underlying causes. Recall that Ranch Hand codes independently of whatever causal sequence is listed on the death certificates before entering the codes into the NCHS software. This explanation does not carry over to the intent categories other than unintentional injury, as contributory cause(s) of death are less of a potential source of confusion due to the intent of the injury.

Another possible explanation pertains to all intent categories. Casualty personnel have access to death investigation information (internal reports) on each case, but AFMR coders do not. One may speculate that Casualty may use this information to unilaterally list a different manner of death as a result of this additional information. This possibility is dimmed by the official administrative regulations (Department of Defense, 1991) which specify that the manner of death will be obtained from the *death certificate*, saying nothing about bringing in additional information. We also note that the agreement between Casualty and the internal report information is weaker than Casualty's agreement with the AFMR. Classification of the manner of death is likely based, for the most part, solely on death certificate information in both primary data sources, although some exceptions to the rule may exist. Most of the discordance may be

explained by administrative or data entry errors or the investigators' coding. However, our analyses suggest that more complex systematic errors may be working as well.

Underlying Cause of Death

The reliability of Casualty information begins to degrade once the desired precision level extends beyond the intent category, as 103 deaths were coded by the investigators into E code groupings which differed from the AFMR. The reliability problem was particularly evident for unintentional injury deaths, and was precipitated by the qualitative deficiencies discussed above, particularly at the four-digit coding level. The precipitous drop in the investigator-derived E code sensitivity when going from three to four digits represents the absolute limit of Casualty data as a reliable surrogate for death certificate information, as represented by the AFMR. This reliability threshold is best exemplified in the suicide E-coding. Using Casualty information, our E codes matched 96 percent of the AFMR's firearm-related suicides at the three-digit level; however, most of these we coded as "unspecified firearm". The sensitivity of our coding for the *specific* type of firearm (four-digit level) was, as seen in Table 6, quite low. Our coding sensitivity approached 100 percent, even at the four-digit level, when the DD1300s conveyed the same amount of information (or more) as the death certificates provided Ranch Hand. Such was the case with air transportation deaths for which the USAF's Casualty personnel clearly documented the type of aircraft on the DD1300 due to the heavy emphasis on aviation in that service branch. This situation was, however, uncommon and it represents the level of information available from the internal death investigations. Unfortunately, this detailed information appears to be used only sparingly at best. The available information on the DD1300s was generally far more enlightening than only having an administratively coded manner of death, but the information was too often vague, leaving the investigators to use non-specific E codes.

The AFMR's more precise E codes at the three-digit level revealed information which was lacking from previous studies. The value of knowing a more precise cause—even at the

three-digit level—for those 61 previously "unspecified cause" accidental deaths should not be discounted, as this is a significant gain in knowledge which may be applied to injury prevention.

The AFMR's four-digit E codes revealed firearm-related information of critical importance in understanding the mechanisms of suicide and insights on controlling access to weapons. For instance, the general lack of military firearms among those which were coded as unspecified weapons in Casualty eases the speculation that suicides associated with military-issued weapons were intentionally concealed in the unspecified category. While 172 unspecified firearm-related suicides remain even after acquiring those 77 specific firearm AFMR E codes, we find no reason to suspect the distribution of specific types of firearms among the remaining cases in the unspecified group would differ significantly from those in the specified group. While certifying authorities may not have always made the distinction between firearms, suicides committed with military weapons do not appear to be as pervasive as some have speculated. The most significant "numeric" gain from AFMR four-digit codes was in motor vehicle traffic accidents where Casualty information was typically vague on both the type of accident and the role of the deceased. The AFMR's four-digit E codes on these 196 deaths revealed the type of accident and the role of the person. Not all types of motor vehicle accidents share the same causal mechanisms; likewise, each would not be prevented in a standard way.

One of the most significant advantages of the AFMR was that the deaths were coded for multiple cause, not just the underlying cause of death. These codes not only disclose the impact of the external cause, but they can be used to acquire additional specificity that E codes cannot convey (Rosenberg and Kochanek 1995). Accessibility to the full range of contributory cause N codes allows investigators to find injuries and poisonings in the N800–N999 range which somehow escaped being E-coded. These substance-related deaths may be found in N960–N989 (poisonings by drugs and other substances) and in N303, N304, and N305, i.e., alcohol dependence syndrome, drug dependence, and nondependent abuse of drugs, respectively.

AFMR Limitations

The most notable limitation with the AFMR is that it is exclusively based on death certificates with all the well-known limitations and biases inherent to the death certification process. The AFMR does not capture the supplemental injury information (date and time of the event, occupational involvement, brief text description of circumstances, etc.) from the death certificates in its database. The percentage of injury-related deaths for which this information is actually provided is not known, but it is desirable to record whatever information *is* available.

Death certificates, and thus the AFMR, lack some military-relevant data such as occupational category, component (e.g., Active Duty, Reserves), unit identification, and other information, although RH inserts rank into the database. Casualty/DD1300 data provide much of this additional information, so this source complements the AFMR. And, as mentioned above, some DD1300s contain more information than the death certificates. The AFMR is not electronically linked to the WCS, nor is there a link to other sources of information such as the Defense Medical Surveillance System (DMSS) or the NCHS.

Mortality Registry for the Military

Detailed information for military mortality is critical, particularly for injury-related mortality. Injuries are the leading cause of death (Helmkamp and Kennedy 1996) and most are preventable, but precise external cause information is needed for effective prevention and control programs. Preventing premature death becomes even more critical in this time of military downsizing in which each servicemember's value to the organization carries a greater weight than before. Our analyses indicate that Casualty-based information lacks the detail necessary to construct an informative NCHS-like mortality surveillance system which uses multiple-cause death certificate information. Given the findings of this study, all military service branches need a mortality information system modeled after the AFMR, but such a registry should eventually include information from supplemental data sources which can sometimes offer more facts than death certificates. Internal investigations, psychological autopsies,

Casualty/DD1300s, and Safety Center mishap data are all good sources of additional information. A "quick fix" approach would be to establish linkage to the NCHS mortality files, prospectively extracting coded death certificate information for military personnel imbedded within the general U.S. population. Obtaining death certificates from foreign jurisdictions would require a more laborious process. Death certificate information may also be acquired in a manner similar to Ranch Hand's current methods.

Conclusions

Casualty and AFMR data are practically interchangeable for general reporting and tracking at the intent category (manner of death) level, despite the troubling discrepancies. Our Casualty-based E codes, however, are increasingly unreliable and uninformative as the desired level of information specificity increases. Therefore, the often-used Casualty data are not a reliable surrogate for death certificate-based data, at least beyond the broad categories of intent. However, no alternative source for mortality data currently exists except for the USAF.

The AFMR should continue to receive the necessary resources to maintain prospective mortality registration while simultaneously acquiring and processing additional years of retrospective data on active duty deaths. The AFMR's expansion into other demographic niches (e.g., persons who have retired from active duty) should continue. This would enable epidemiologists to assess the longer-term effects of USAF service on health. Supplemental information from the death certificates pertaining to injury deaths should be included in the AFMR database in order to further assess the circumstances surrounding the event.

A DoD-wide mortality registry should be developed, using the AFMR as a prototype. Mortality registry officials should establish a formal relationship with the WCS to reconcile differences regarding who died and their manner and cause of death. This would also enable a mortality registry to include duty status, military occupational code, and other information unique to Casualty. An all-service mortality registry should access or link with data other than the two data sources used in this study, including information from the internal investigations and other

relevant information from DoD databases. Until a DoD mortality registry is operational, the mortality surveillance on military personnel will continue to be inferior to that afforded the general U.S. population.

Table 1. Comparison of the quality of E- coding specificity for underlying cause of death, Air Force Mortality Registry (1991–1998) vs coding from Casualty data (1990–1998), E codes (percents) by qualitative category for each manner of death

		Injury Intent Category (Manner of Death)					
	Coding specificity	Unintentional (column %)	Suicide (column %)	Homicide (column %)	Terror/KIA* (column %)	Undet intent (column %)	TOTAL (column %)
AFMR	Precise	541 (67%)	266 (62%)	38 (49%)	42 (97%)	9 (53%)	896 (65%)
	Imprecise	260 (32%)	164 (38%)	36 (47%)	1 (3%)	8 (47%)	469 (34%)
	Nonspecific‡	10 (1%)	0 (0%)	3 (4%)	0 (0%)	0 (0%)	13 (1%)
	Coded as Illness or Unknown§	–	–	–	–	–	3 (<1%)
	Missing from dataset††	–	–	–	–	–	0 (0%)
	TOTAL	811 (100%)	430 (100%)	77 (100%)	43 (100%)	17 (100%)	1,381 (100%)
Casualty	Precise	279 (32%)	160 (36%)	19 (23%)	39 (94%)	7 (47%)	504 (34%)
	Imprecise	518 (59%)	271 (61%)	56 (69%)	2 (6%)	6 (40%)	853 (58%)
	Nonspecific	76 (8%)	11 (3%)	6 (7%)	0 (0%)	2 (13%)	95 (6%)
	Coded as Illness or Unknown§	–	–	–	–	–	18 (2%)
	Missing from dataset‖	–	–	–	–	–	5 (<1%)
	TOTAL	873 (100%)	442 (100%)	81 (100%)	41 (100%)	15 (100%)	1,479† (100%)

* *KIA = killed in action (hostile fire deaths).*

† Casualty totals includes 4 deaths for which the DD Form 1300, used to derive E codes, was missing (2 unintentional, 2 KIA/terror), not included in table cells. Totals differ by 97 deaths due to the following: AFMR data not available prior to 1991; Casualty listed 196 additional deaths in 1990. For 1998: AFMR has 127 injury deaths coded; Casualty data incomplete (91 deaths with "pending" information) in 1998.

‡ Unspecified codes are E928.9 (accident), E929.9 (late effects of injury), E958.9 (suicide) , E968.9 (homicide), and E988.9 (undetermined intent)

§ This category represents deaths coded as either illness-related or as of unknown cause (N799), but were coded as injury-related (E coded) in the other dataset. Category also includes 7 deaths prior to 1998 where the DD1300 and the Casualty electronic data file listed the manner of death as "pending". Our last update of that file from WCS was in October 1999. Their contributions to the matrix show up in the last column, TOTAL , since these deaths cannot be categorized by an injury-related manner of death.

|| These deaths were not listed in the other dataset.

*Table 2. Qualitative level of agreement in E- coding specificity with kappa statistic for underlying cause of death Air Force Mortality Registry vs coding from Casualty data, USAF, 1991–1998**

		Casualty					
	Coding specificity	Precise	Imprecise	Nonspecific	Illness	Missing	TOTAL
AFMR	Precise	*434*	322	58	7	3	824
	Imprecise	4	*406*	17	2	0	429
	Nonspecific†	2	1	*8*	1	0	12
	Illness or Unknown‡	0	4	0	*0*	2	6
	Missing on roster	0	0	0	0	*0*	0
	TOTAL	440	733	83	10	5	1,271

Kappa (κ), *unweighted*: observed qualitative agreement = 66.6%, expected agreement = 42.0%, $\kappa = 0.42$ (fair to moderate agreement), $p = 0.000$

Kappa (κ), *weighted*: observed qualitative agreement = 89.8%, expected agreement = 88.1%, $\kappa = 0.30$ (fair agreement), $p = 0.000$
Kappa cell weights (from top to bottom, from left to *diagonal*): 1 \ .85 1 \. 4 .85 1 \ .2 .4 .85 1 \ 0 0 0 0 1

** Years are different from those used in Table 1 since this table presents paired data. Only those records included in both datasets could be used.*
† Non-specific (unspecified) codes are E928.9 (accident), E929.9 (late effects of injury), E958.9 (suicide) , E968.9 (homicide), and E988.9 (undetermined intent)
‡This category represents deaths coded as either illness-related or as of unknown cause (N799).

Table 3. USAF injury-related mortality by manner of death, 1991–1997, AFMR vs investigator-coded Casualty data

Data Source	**Manner of death (intent category)**	**Freq**	**Percent**
	Unintentional injury	726	47
	Suicide	394	25
	Illness	285	18
AFMR	Homicide	72	5
	Hostile fire/terrorism	42	3
	Injury, undetermined intent	16	1
	Undetermined cause†	13	1
	TOTAL	1548*	100
	Unintentional injury	719	46
	Suicide	392	25
	Illness	294	19
Casualty	Homicide	71	5
	Hostile fire/terrorism	42	3
	Undetermined‡	25	2
	TOTAL	1543	100

**5 deaths in AFMR not listed in Casualty are distributed as follows: suicide (3) and illness (2).*

† Undetermined cause in AFMR is exclusively N797-N799 (ill-defined and unknown causes)

‡ Casualty's official "Undetermined" category contains N797-N799 (unknown cause, 8 deaths); E980-E989 (injuries of undetermined intent, 10 deaths), and "determination pending" (7 deaths).

*Table 4. Comparison intent categories for non-terrorist, non-hostile fire deaths, AF Mortality Registry vs Casualty data for 1,660 USAF mortality records, 1991–1998**

	AFMR Manner of Death							
Casualty Manner of death	Unintentional injury	Suicide	Homicide	Undeter intent†	Legal Intervention	Illness	Unknown‡	TOTAL
Unintentional injury	774	1	1	1	0	2	0	779
Suicide	1	413	0	2	0	1	0	417
Homicide	0	0	73	0	1	0	0	74
Undetermined††	1	0	0	11	0	3	5	20
Illness	9	0	0	1	0	302	3	315
Pending‖	2	2	0	1	0	2	0	7
Not listed (missing)	0	3	0	0	0	2	0	5
TOTAL	787	419	74	16	1	312	8	1,610¶

AGREEMENT PARAMETERS:
1,578/1,610 deaths coded into same intent category. Kappa (κ), unweighted: observed agreement = .98, expected agreement = .328, $\kappa = 0.96$ (almost perfect agreement), $p = 0.000$.
"Pending" and "Unknown" excluded from analysis due to lack of comparability with any category from the other data source.

Sensitivity (sens), specificity (spec), predictive value of a "positive" classification (PVP), and classification accuracy (acc) of Casualty information compared to "gold" AFMR, major intent categories, Casualty "pending" included:

Unintentional injury:	sens = 774/787 = 98%	spec = 825/830 = 99%	PVP = 99%	acc = 1599/1617 = 99%
Suicide:	sens = 413/419 = 99%	spec = 1194/1198 ≈ 100%	PVP = 99%	acc = 1607/1617 ≈ 100%

Homicide:	sens = 73/74 = 99%	spec = 1616/1617 ≈ 100%	PVP = 99%	acc = 1615/1617 ≈ 100%
Illness:	sens = 302/312 = 97%	spec = 1291/1305 = 99%	PVP = 95%	acc = 1593/1617 = 95%

* *Casualty data files for 1998 were incomplete at the time of the analysis, only 68 deaths. These cases were included since they could be paired with AFMR death. No AFMR data was available for 1990, so no pairing was possible.*

† *Injury death of undetermined intent. (See ‡ below).*

‡ *AFMR coded as N797-N799 (ill-defined and unknown causes).*

§ *"Undetermined" in Casualty data is used not only for injuries of undetermined intent, but also for deaths in which the investigators coded as N797-N799 (ill-defined and unknown causes). The AFMR is used to "reclassify" deaths with unknown causes into the more appropriate "Unknown" manner category*

|| *Category for deaths in which the Casualty manner of death was still listed as "pending" at the time of the analysis, not including 1998 deaths.*

¶ *Total does not include deaths coded as "Pending" in Casualty.*

Table 5. E-coding discordance for underlying cause of death (external cause broad groupings and unspecified accidents) between AFMR and Casualty data, selected injury mortality underlying cause groupings, USAF, 1991–1998

		AFMR E code grouping (all groupings are unintentional injury unless noted otherwise)										
Casualty Cause (E code grouping)	**Different cause in AFMR* (N)**	Rail (E800-E807)	MV traffic (E810-E819)	Other road vehicle (E826-E829)	Water transport (E830-E838)	Air transport (E840-E841)	Poisoning, non-drug (E860-E869; E982†)	Falls (E880-E888)	Environ (E900-E909)	Drown/ Suffoc (E910-E915)	Unspec accident (E928.9; E929.9)	Other accident (E916-E928.1-.8)
Unspecified accident (E928.9; E929.9)	64	1	42	2	1	4		7	3	1	_	3
Drowning (E910-E915)	9				5	1			3	_		
Poisoning (E860-E869)	3‡						_			2		
Falls (E880-E888)	2§					1		_				
Illness/unknown (N001-N799)	9‖						1			2	1	1

** These numbers represent 88 of the 103 AFMR "reclassifications", i.e., where AFMR cause coding differs from Casualty-based codes. Many of the discordant cause of death codes not shown here appear in Table 4 since the discordance was first and foremost on the manner of death; however, some remaining cause groupings with only 1 discordant classification are not shown.*

† Manner of death is injury of undetermined intent; 1 of the Casualty-listed illnesses was coded as such in the AFMR.

‡ Total includes 1 accidental poisoning classified by AFMR as an illness (not shown).

§ Total includes 1 accidental fall classified by AFMR as an illness (not shown).

‖ Remaining AFMR illness reclassifications (not shown): medical misadventures, E870-E876 (2); adverse drug reaction, E930-E949 (1); and, late effects of unspecified accident, E929 (1). This category contains N797-N799 (ill-defined and unknown causes).

Table 6. Sensitivity of selected investigator-derived three-digit and four-digit E codes, based on Casualty information, compared to E codes obtained from the Air Force Mortality Registry, 1991–1998

Underlying cause of death (AFMR E code)	Number of deaths	Number of deaths based on Casualty	Sensitivity
3-digit level of coding			
Motor vehicle collision with pedestrian (E814)*	16	11	69%
Motor vehicle accident, non-collision (E816)	78	63	81%
Accidental alcohol poisoning (E860)	9	7	78%
Suicide by hanging or suffocation (E953)*	90	81	90%
Suicide by firearm or explosives (E955)	253	244	96%
Suicide by cutting/piercing (E956)*	8	5	63%

Underlying cause of death (AFMR E code)	Number of deaths	Number of deaths based on Casualty	Sensitivity
	4-digit level of coding		
Aircraft accident: non-military, non-commercial aircraft (E841.5)	18	18	100%
Suicide by hunting rifle (E955.2)	11	0	0%
Suicide by tranquilizers, psychotrophic drugs (E950.3)	9	5	56%
Suicide by handgun (E955.0)	57	6	11%
Suicide by shotgun (E955.1)	32	12	38%
Homicide by handgun (E965.0)	12	2	17%

* *Highest level of coding possible within ICD coding scheme*

*Table 7. Comparison between investigator E codes from DD1300s, investigator E codes from detailed casualty reports, and AF Mortality Registry E codes for 27 female deaths, 1990–1998**

Source of E codes
(number of records with those E codes in parentheses)

Casualty†	**Internal report**	**AFMR**
Manner: accident		
E841.1 (1) military air	E841.1 (1) military air	E841.1 (1) military air
E928.9 (2) unspecified	E819.2 (1) motor cyclist	[missing] (1)
	E818.8 (1) MV non-collision	E928.9 (1) unspecified
Manner: suicide		
E950.4 (2) other drugs/meds	E950.4 (1) other drugs/meds	E950.4 (1) other drugs/meds
	E950.5 (1) unspecified drug	E950.5 (1) unspecified drug
E950.5 (1) unspecified drug	E950.5 (1) unspecified drug	E950.3 (1) tranquilizers/psycho
E952.1 (3) CO, other	E952.0 (2) MV exhaust	E952.0 (1) MV exhaust
	E952.1 (1) CO, other	E952.1 (1) CO, other
		[missing] (1)
E955.4 (11) unspecified firearm	E955.4 (10) unspecified firearm	E955.4 (6) unspecified firearm
	E955.0 (1) handgun	E955.0 (4) handgun
		[missing] (1)

Source of E codes (number of records with those E codes in parentheses)		
Casualty†	**Internal report**	**AFMR**
E958.8 (1) other specified means	E822.0 (1) *Accident*: MV non-traffic	[missing] (1)
E958.9 (2) unspecified means	E950.4 (1) other specified drugs E950.3 (1) tranquilizer/psycho	E950.3 (2) tranquilizer/psycho
Manner: Homicide		
E965.0 (1) handgun	E955.4 (1) *Suicide:* unspecified firearm	E965.0 (1) handgun
E965.1 (1) shotgun	E965.4 (1) unspecified firearm	E965.1 (1) shotgun
E966 (1) cut/pierce	E966 (1) cut/pierce	E966 (1) cut/pierce

Level of Agreement and Kappa Statistic (κ)

[Casualty] and [Internal Report]: Observed agreement = 57%; expected agreement = 20%; $\kappa = 0.47$ (moderate agreement)

[Casualty] and [AFMR]: Observed agreement = 63%; expected agreement = 7%; $\kappa = 0.60$ (high moderate/substantial agreement)

[AFMR] and [Internal Report]: Observed agreement = 46%; expected agreement = 13%; $\kappa = 0.38$ (fair agreement)

* *AFMR data not available for 1990; Casualty data incomplete (127 cases) for 1998.*
† *E codes in this category were derived from manner of death in Casualty electronic file plus the information on the DD1300.*

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CHAPTER 3

Suicide in the U.S. Air Force, 1990–1998: Descriptive Epidemiology Using Death Certificate Multiple-Cause Information

Abstract

The epidemiology of suicide (*N* = 480) in the U.S. Air Force (USAF) active duty population during 1990–98 is described, using a new source of multiple-cause mortality information developed for epidemiologic use. This period included a seven-year period (1991–97) in which suicides occurred at a sustained rate of 12 per 100,000 servicemembers. Officers and enlisted exhibited different time-related trends in incidence rates. Crude bivariate rates were not valid due to heterogeneity within strata of gender, rank, age, or race. Significant qualitative statistical interaction on the multiplicative scale was noted between gender and corps in a multivariate Poisson regression model. Female rates were higher than male rates in the officer corps, the opposite of the enlisted corps' pattern. White enlisted males had the highest adjusted rate, 17.1 (15.4, 19.0) per 100,000 person-years, and the highest burden, 346 suicides. Nearly 60 percent of suicides were firearm-related, with male and enlisted rates three times higher than female rates for gun use in suicide. Overall, the gun:non-gun suicide ratio showed a significant linear decrease as rank and age increased, although senior officers and the 35–39 age group deviated from that trend. Females committed a greater proportion of USAF gun-related suicides as rank and age increased.

Introduction

The Post-Cold War Era ushered in dramatic operational and psycho-social changes within the U.S. military. The long-standing nuclear readiness posture at fixed facilities with large standing forces was replaced with a myriad of new missions far removed from the preparation for a World War III. These post-Cold War missions have produced uncertainty regarding whether the next mission would be combat-related or humanitarian, peace-making or peace-keeping.

Many military installations overseas were closed in favor of deploying our forces from those bases which remained which are mostly within the U.S.' boundaries. Without competition for the role of the world's military "superpower", and with the perception that the new missions would require fewer servicemembers, the military was forced to down-size. Job security for servicemembers was threatened while, at the same time, the number of deployment missions increased. As a result, the military's overriding operational objective was (and still is) "to do more with less". The military's suicide rate increased coincidentally with these transitions. The suicide rate in the U.S. Air Force (USAF) began to increase in the mid-1980s, but higher rates (i.e., above 10 suicides per 100,000 servicemembers) were not sustained until the 1990s (Helmkamp and Kennedy 1996; Centers for Disease Control and Prevention (CDC) 1996b). An epidemiologic description of the entire USAF suicide "epidemic" of the 1990s, needed to better understand the dynamics of the high rates, has not been published previously.

Recent population-based descriptive studies on military suicides (Rothberg and McDowell 1988; Helmkamp 1995; Helmkamp and Kennedy 1996) rely on the usual data source, the Casualty/mortality files from the Department of Defense (DoD) World-wide Casualty System (WCS). The limitations of this data have been defined elsewhere (Helmkamp 1995; Hansen and Jones 1996; Atlas of Injuries in the Armed Forces 1999). The main limitation of the Casualty data is that multiple cause of death information recorded on death certificates is lost in the WCS' administrative summary process. The primary tool for researchers using Casualty data has been the Department of Defense Form 1300 (DD1300), Report of Casualty, on which the

manner of death and the underlying cause of death are annotated. These determinations are not made by nosologists using multiple cause of death information for research purposes, rather by administrative personnel who fulfill their operational requirements by transcribing only the manner of death into an electronic data file along with a brief description of what they perceive to be the underlying cause of death onto the DD1300s.

In an earlier study (Copley, Smith, & Grayson 2000), we noted evidence which suggested that, without consideration of the full multiple cause information on the death certificate, the WCS' summaries sometimes unwittingly annotate a contributing cause (e.g., sudden cardio-pulmonary failure, or blunt trauma to the head) instead of an external, underlying cause of death (e.g., firearm/gunshot). We also noted that the sometimes ambiguous information on the DD1300s produced equally nonspecific E codes for injury-related deaths. The four-digit E codes derived from Casualty information were generally unreliable for research purposes, compared to multiple-cause death certificate information from the newly-developed Air Force Mortality Registry (AFMR). The AFMR also offers more complete case ascertainment, as it has information on three active duty suicides that Casualty did not list (Copley, Smith, & Grayson 2000).

This alternative source for USAF mortality information is maintained by nosologists who acquire copies of death certificates, then code directly from those documents for multiple cause of death according to the *International Classification of Diseases* (ICD), *9^{th} Revision* format, including the *Supplemental Classification of External Causes of Injury and Poisoning,* or E codes. The nosologists then use algorithms developed by the National Center for Health Statistics (NCHS) for determining the underlying and contributing cause(s) of death. The AFMR offers twice the E-coding specificity level as those E codes that we derived from Casualty information (Copley, Smith, & Grayson 2000). Our current study uses the AFMR as its primary data source, but Casualty data are used as a supplemental source of information for occupational categories which are not obtainable from death certificates.

The primary purpose of this study is to locate and describe high-rate areas of suicide in the study population on which more focused intervention programs may be directed. The specific underlying (external) cause of suicide and contributing causes (e.g., alcohol intoxication) will be the key feature of this description, enabled by the multiple-cause coding offered by the AFMR. This information will help generate hypotheses on motive since levels of suicide intent and impulsiveness may be manifested by the means or contributing causes of suicide. The descriptive process will quantify the USAF suicide experience in terms of absolute rates, rate ratios, rate differences, and population attributable fractions.

The study base from which suicides will be described is the USAF active duty population during the study period 1990–1998. A greater use of stratified and multivariate analysis will be employed in this study than in previous studies in order to assess both independent and combined associations between group membership and the rate of suicides.

Methods

The methods used in this study for data collection have been described previously (Copley, Smith, & Grayson 2000) The supplemental data source for calendar year 1990 was, as in the previous studies, from the Casualty files. These data include information obtained and E-coded from DD1300s. The investigators' E-coding, derived from Casualty information, agreed with AFMR E-codes 76 percent of the time on the three-digit E code category for the underlying cause of death (Copley, Smith, & Grayson 2000), thus Casualty data were a relatively reliable substitute at that level of coding. No comparison was made on the contributing cause(s) of death since neither Casualty electronic data nor DD1300s have that information. Occupational job classifications for all years were obtained from Casualty data. The investigators linked these two sources of data by decedents' social security number.

Rank was categorized by two different schemes: four categories (two each for enlisted and officers), and five categories (three for enlisted, two for officers). The choice of categorization scheme was determined by "natural" rate cutpoints emphasizing rate disparity,

statistical efficiency (power), rate linearity (trend), and descriptive ability. Regardless of the number of categories, the groupings represent clear military socio-cultural distinctions in both on- and off-duty life which may account for differences in suicidality.

Only those USAF active duty deaths due to suicide were used in this study. Suicides during the period 1991–1998 were defined as those deaths in which the AFMR listed an ICD-9 E code of E950–E959 as the underlying cause of death. Suicides for 1990 were defined by the manner of death in the Casualty files, i.e., those deaths administratively coded with a manner of death as "Suicide".

Socio-demographic categories available for this study, each a potential risk factor for suicide, were analyzed with Stata (StataCorp 1999) statistical software. Suicide rates were computed per 100,000 person-years for each specific means of death when feasible. Suicide rate ratios (SRRs) and 95 percent confidence intervals were calculated according to methods recommended by Rothman and Greenland (1998). The bivariate analyses included stratification of each variable (e.g., rank categories) by sex.

For analyses involving occupational groups, rate-based analyses were confined to 1994–1998 since denominator data prior to 1994 were not posted to the on-line data source. Job codes prior to 1994 used a different classification system, and the method of aggregating and reporting denominators by occupational groups was also different. Old codes may be translated into current codes, but such a task was beyond the scope of this study since occupation is not the key issue. Numerator-based analyses were, however, based on the complete case series for the study period.

Poisson regression models, commonly used for modeling of incidence density data on rare events such as suicide (Rothman and Greenland 1998; Breslow and Day 1980) were used to adjust suicide rates in a multivariate setting of sex, rank, and race. Standard indicator variables were created in Poisson models to represent each level of rank or age in order to assess possible non-linear rate patterns within those ordered categories.

Results

Time

A total of 480 suicides accrued in the active duty Air Force population from 1990 through 1998. The rates increased to historic highs during the middle of the decade but had returned to a more normal rate by the end of the study period (Figure 1). A polynomial model trend line smoothes and simplifies the USAF suicide rate while providing a fit to the data which accounts for 85 percent of the variation in the annual suicide rates. By 1998, rates had returned to levels seen in the early part of the 1990s. Enlisted rates dictated the pattern of the overall USAF rates since that group contained the bulk of the accumulated person-years and suicides; however, the officer pattern was vastly different (Figure 2). The officer rate was 3.6 per 100,000 in 1993. Over the next three years the rates increased to 4.9, 7.6, and 15.6 per 100,000. In that peak-rate year (1996) for officers, enlisted rates were 12.4 per 100,000, the only year in which officer rates exceeded either enlisted or USAF rates. Officers joined the USAF decline in suicide rates after 1996, decreasing in 1998 to a decade-low rate.

Officers averaged 4.7 suicides per year prior to 1996, and even in the peak-rate year (1996) they committed only 12 suicides. The absolute difference between the pre-1996 officer average suicide incidence and the 1996 peak was only seven suicides, while this group averaged 10 fewer annual suicides after 1996. The officers' influence on the overall rate was weak since the enlisted corps contributed over 90 percent of the incidence and nearly 80 percent of the person-years during the period. For the enlisted, the absolute suicide incidence difference between the 1994–1995 plateau (mean = 58 suicides per year) and post-1995 (mean = 38 suicides per year) is 20, even though the incidence *rate* decrease is less drastic than that of officers. Overall, the combined (officer and enlisted) post-1996 decrease in absolute incidence resulted in an average net reduction of 20 suicides per year—from a pre-1996 average incidence of 58, to 38 suicides in 1997–1998. Gender and age category yearly rates

(not shown) generally conformed to Figure 2's pattern except for males in the 35 years-and-over age group where rates increased over the last two years of the period.

Socio-demographic Comparisons

Suicide rates were highest in males, SRR = 2.7 (1.9, 4.1); whites, SRR = 1.4 (1.1, 1.8); and enlisted personnel, SRR = 2.4 (1.7, 3.3) (Table 1). Rates by age categories did not differ significantly, as SRRs across those three categories were flat and statistically indistinguishable from 1.0. Stratification of those rates indicates heterogeneity within socio-demographic factors which will be reported below in detailed analyses. Rate patterns over time will also be examined.

SEX

Quantitative statistical interaction was noted between gender and the three age groups (χ^2 test of heterogeneity, $P = 0.04$) (Table 1). This statistical relation is illustrated in Figure 3 in which the magnitude (but not the direction) of the gender-based SRR depends upon the age category. The age groups are stratified more finely in Figure 3 to show the decline in the female age 40+ rates, not seen by Table 1's categorization scheme. Males experienced higher suicide rates in each age category, but the rate difference (12.3 per 100,000) and rate ratio (5.8) were each most pronounced in the 17–24 age interval. This rate difference narrowed to 4.1 suicides per 100,000 in the 35–39 age category before again widening (Figure 3). The overall crude rate flatness across the age spectrum seen in Table 1 fails to hold for females. The narrower age intervals of Figure 3 reveal a decline in the female suicide rate in the oldest age group not seen when only using three age categories, as was presented in Table 1. A Poisson model-based Wald testing indicated that the male association with suicide relative to females may be stratified by two age groups: <25 years, SRR = 5.7 (2.5, 13.1); and 25+ years, SRR = 2.0 (1.3, 3.1).

Greater heterogeneity (χ^2 test, $P < 0.01$) in the male SRR becomes apparent when stratifying by rank category (Figure 4) in which the number of rank categories was expanded

from four (in Table 1) to five to show the two within-corps plateaus in the overall suicide rate. A more precise and equally heterogeneous rate classification was noted when dichotomizing the male-suicide relation (SRR) by corps, officers = 0.5 (0.3, 1.1) and enlisted = 4.1 (2.6, 6.8). Significant qualitative (directional) statistical interaction for the gender-corps relation was noted (χ^2 test of heterogeneity, $P < 0.01$) Male rates were higher than female rates in the enlisted corps, while the reverse occurred in the officer corps (Figure 4).

RANK

The crude SRR for the enlisted corps (E1–E5 and E6–E9 in Table 1) versus the officer corps was 2.4 (1.7, 3.3), and this was the only rank categorization scheme in which the rate ratios were statistically different from the null. These estimates were based on suicide rates per 100,000 which ranged from 13.5 to 14.3 each year in the enlisted corps, and 4.7 to 6.0 per year in the officer corps. These rates are not generalizable to both males and females as noted above.

RACE

Whites showed a mildly elevated (but statistically significant) rate compared to Blacks and other non-whites, SRR = 1.4 (1.1, 1.8). However, whites' statistical relation with suicide differed significantly by corps (χ^2 test, $P = 0.02$): $SRR_{white|officer} = 0.6$ (0.3, 1.6) and $SRR_{white|enlisted} = 1.6$ (1.3, 2.1), not observable in Table 1. Enlisted whites showed a suicide rate of 15.4 per 100,000 while officer whites' rate was 5.6 per 100,000. Non-whites' incidence rate was 9.5 suicides per 100,000 servicemember-years in *both* corps (data not shown).

AGE

The absolute burden, or incidence, of suicide was not evenly distributed throughout all age categories despite the parity in the crude rates as seen in the marginal totals in Table 1 (see Figure 3). The younger and middle age groups, with the exception of the below-19 age group, contributed the most suicides. The nearly static unadjusted suicide rates across the age categories (Table 1) are the result of the combination of the gradual decline in the male suicide

rate (after the 20–24 peak) and the remarkably consistent increase in the female rate through the first five age categories (Figure 3).

Multivariate Analysis

Results of Poisson multivariate regression modeling adjusted the suicide rates by sex, race, and rank (Table 2). Age was not modeled given its co-linear relationship with rank categories within corps. The influence of rank on suicide rates was also more predictable than was the age effect. Statistical interaction between sex and corps was highly significant to the model, as indicated by the likelihood ratio test (LRT) (Table 2). Male rates were higher in both whites and non-whites, but not in both corps. Female officers had higher rates than did males within the officer corps. Enlisted rates were higher than officer rates in both whites and non-whites, but only in males. Enlisted white males (EWM), the reference parameter (constant) in the Poisson model, had the highest suicide rates. Crude suicide rates given in Table 1, however, are valid for race-ethnic group comparisons since these terms were not found to interact with other model parameters. Differences between each race-ethnic group's crude (Table 2) and the sex- and corps-adjusted rates (Table 2) were negligible. Female rate estimates among the model's covariate patterns were statistically indistinct due to wide confidence intervals. The Poisson model fit the actual data extremely well (Table 2).

Specific Causes (Means) of Suicide

Guns and explosives were the primary external cause of suicide, both overall and within all socio-demographic categories (only sex and corps shown, Table 3). Firearm-related suicides are analyzed in greater detail further below.

Hanging or asphyxiation was the external cause of death in over 20 percent of USAF suicides, male SRR = 5.8 (1.9, 28.8), enlisted SRR = 1.8 (1.0, 3.5). Suicides by gases or substances comprised about 15 percent of the suicide mortality. Motor vehicle gas/carbon monoxide poisoning was the external cause for the majority (58 percent) of suicides in this

category, $n = 41$, male SRR = 2.3 (0.7, 11.7), enlisted SRR = 1.7 (0.7, 5.6). Twenty-seven of these suicides were the result of intentional (over)dosing of drugs and medicaments[2], the most common types being tranquilizers and hypnotics, male SRR = 0.5 (0.2, 1.4), enlisted SRR = 1.0 (0.4, 3.6). Analgesics or antipyretics were the external cause for four of the poisoning suicides, and seven were given "unspecified drug" or "other specified drug" E codes. Drugs and medicinal substances were specified as the means of death in 10 of the 12 suicides in the medical occupations which were not gun-related. The statistical association between the medical occupational group and the use of drugs/medicaments (given suicide) was moderately strong, SRR = 3.1 (1.3, 6.4). No other external cause category contained more than nine suicides, as 452 of the 480 suicides (94 percent) were the result of guns, hanging/ asphyxiation, or poisonings.

Male rates are remarkably similar to enlisted rates, while female and officer rates are likewise similar (Table 3). An exception to this pattern is noted in the hanging/asphyxiation category in which the officer rate (2.8 per 100,000) is over three times higher than the female rate (0.5 per 100,000). Another deviation from the general pattern is seen in the drugs and medicinal poisoning sub-category where the female rate (1.2 per 100,000) was higher than the officer rate (0.7 per 100,000). Alcohol or drugs were listed as a *contributory* cause of suicide in only five suicides, four of those in the gun-related (underlying cause) category, and the other in a suicidal gassing (data not shown). Among other psychiatric contributing causes, depression was the listed in nine suicides, six in suicides by gasing/substances and four gun-related suicides (not shown).

Firearms as a Means of Suicide

USAF suicide mortality was predominantly related to firearms (Table 3). Death certificate information from the AFMR gave precise four-digit E codes on the type of firearm for

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[2] "Medicaments" is a term used by the NCHS that represents suicides from medicinal agents.

77 gun-related suicides in which the investigators' Casualty-based E codes were *Other and Unspecified Firearm* (E955.4) or *Unspecified firearm* (E955.9) codes, data not shown. Still, 182 gun-related suicides (61 percent) were left unspecified according to death certificate information in the AFMR. In the suicides for which the death certificate specified the type of firearm, handguns were implicated in 57 percent, shotguns in 32 percent, and hunting rifles in 11 percent. Fifty-nine percent of both USAF and male suicides during the period were inflicted by a firearm, while 53 percent of the female suicides were gun-related (Table 4-A and Table 4-B). USAF and male gun-related percentages decreased to 53 percent after the 1995 peak suicide year, and the female percentage remained about the same (55 percent), data not shown. The percent of USAF suicides committed by females and the female gun-specific suicide rate each increased as the rank category increased (Table 4-A). The percent of USAF female suicides which were gun-related (by death certificate) was a function of both corps and age, as senior enlisted and senior officer suicides were most often gun-related in contrast to the junior grades within each corps (Table4-A). The crude gun-related suicide incidence rates were 8.0 per 100,000 servicemembers in males and 2.6 per 100,000 in females (Table 3, Table 4-A, and Table 4-B), SRR = 3.1 (1.8, 5.4), but female rates were higher in officers, both junior and senior (Tables 4-A and 4-B). Male gun-related suicide rates were higher in all age categories except the age 40-and-above group in which female rates were higher (Table 4-B). Rate ratios by race were unremarkable (data not shown). Only one of the 130 USAF gun-related suicides committed by the most junior airmen (E1–E4), and two of those 92 gun-related suicides completed before age 25, were committed by females (Table 4-A and Table 4-B).

The gun:non-gun ratio of suicides by rank category (Figure 5) and age category (Figure 6) each show that the ratio decreases with increasing rank and age. Officer suicides, unlike enlisted, were slightly more likely to be inflicted by a non-gun means, but only in junior officers did that ratio actually fall below 1.0. Generally, the suicide incidence was low in the senior enlisted (E8–E9) category and throughout the officer corps (Figure 5). The gun-use ratio only fell below 1.0 in the oldest age group (Figure 6). Readers should also note the differing scales

of the *y*-axes of Figures 5 and 6, and that the USAF suicide incidence is concentrated far more by rank than by age, for both gun and non-gun related suicides.

The occupational groups with the highest percentage of gun-related suicides were logistics (69 percent), support (66 percent), and operations (60 percent), data not shown. Each of these occupational groups experienced lower than expected proportions of suicides by hanging or strangulation (the second most likely means of suicide), with 12 percent, 14 percent, and 17 percent respectively. A sub-element of the logistics group, aircraft maintenance/avionics, used a gun in suicide 78 percent of the time. Security forces, an occupational sub-group within the support category, committed 34 of their 44 suicides (77 percent) with firearms.

Occupation as a Suicide Risk Factor

No statistically significant differences in rates were found among the occupational groups (Table 5). In Table 5, the number of suicides for each (sub)group in the Suicide column represent the *entire* case series for the study period, while the rates are based on 1994–1998 data only (See *Methods*). The logistics occupational group, representing 36 percent of the USAF population (USAF Personnel Center 1999), experienced 45 percent (n = 213) of USAF's suicides during the period, the most of any occupational group. Within that broad occupational category, aircraft maintenance personnel committed 116 of those suicides, 14 more than expected based on their population proportion (USAF Personnel Center 1999). Suicide incidence in the support occupational category was dominated by security personnel. Officers and enlisted are included in each major occupational group, although most of the sub-categories presented in Table 5 are exclusively enlisted unless indicated otherwise in the footnotes. Rate ratios were not statistically different from 1.0.

Discussion

Data Sources

The three additional case findings obviously did not impact the overall USAF suicide incidence or rates due to the already large suicide burden, but they contributed to the validity of the study. AFMR information allowed us to reacquire the information on the type of firearm which was lost when the death certificate information was transposed by Casualty personnel. Death certificate information still left us with a majority of unspecified firearm E codes, showing one of the many problems encountered with using that information. Despite the methodological limitations of using death certificates, more information was generally available on non-firearm suicides, particularly for gases, drugs, and other substances in which the specific agent was often identified. The biggest advantage of the AFMR is that the suicides are already coded by well-trained nosologists, thus this is a more expedient means of conducting this type of suicide research. AFMR E-coded data is likely more valid than those codes we derived using DD1300 and Casualty data.

Dependence on mortality data will diminish as additional years of multi-source USAF suicide surveillance data (CDC 1999b) on suicide completions, attempts, and gestures accrue. This developing source of information contains demographics, details of the events, pre-event use of prevention services, and associated psychological, social, behavioral, and economic factors (CDC 1999a). This data has been prospectively collected only since 1997, so mortality information will continue to be vital for analyzing suicide data over the longer term, and will provide a source of data continuity between the pre- and post-registry periods.

Suicide Rates

The recent decline in the overall USAF suicide rate from its mid-decade highs was statistically significant ($P < 0.002$) (CDC 1999b). The decline in rates starting in 1996 appeared one year before a vigorous suicide prevention program began, and this program was

incrementally expanded to its current level of activity. The officer suicide rate, on the rise since 1993, did not subside until the program was implemented in 1997. The program seems to have had a greater impact on the rapidly-escalating suicide rates in officers than in the enlisted, although the absolute decline in suicides in the enlisted most certainly represents a public health success, assuming the decrease is largely attributable to the prevention program.

One of the key prevention program components is the removal of institutional barriers to seeking mental health services. Utilization of mental health services has, in the past, been particularly stigmatizing for officers, as they have generally perceived a visit to the mental health clinic as a career-threatening gesture. Perhaps the prompt and drastic decline in the officer suicide rate may be attributed to the de-stigmatizing effect of that new policy. Officer rates are also more sensitive to relatively smaller changes in absolute incidence compared to the enlisted corps, as their denominator is approximately one-fourth as large as the enlisted corps. While the suicide prevention program officially started in 1997, some of the social support and command involvement features of the program were *de facto* policies several months earlier (investigator observation). One may speculate that these preliminary prevention policies improved the enlisted troops' psychosocial condition more than that of officers, thus the enlisted suicide rate decreased earlier. Another explanation may be labeled "benevolence upward expansion" in which the junior (company grade) officers begin "taking care of their (enlisted) people" in concert with the program's objectives soon after the program's implementation, as they were under command pressure to do so. At some point, it may have become obvious that the higher-level (field grade and general) officers likewise needed to address the psychosocial needs of *their* subordinates, those company-grade who were experiencing their own set of stresses.

Crude or marginal suicide rates need to be adjusted or stratified by gender, race, and rank (or corps) in order to report valid estimates. To generalize these rates by saying that officers have low rates while enlisted have high rates, or that male rates are lower than female rates, is to marginalize the socio-demographic niches which represent "the exception to the rule". These exceptions may also provide vital clues on causal mechanisms of disease and

injury, but the deviations will likely be missed if not reported. Military policymakers need the full set of information to monitor the success of the suicide prevention efforts.

The unadjusted rates and rate ratios in this study show little difference from previous studies (Rothberg and McDowell 1988); Helmkamp 1995) except for suicide rates for the "other" (non-white, non-Black, which includes Hispanics, Asians, and other minority groups) race-ethnic group. Helmkamp reported their rate as 6.4 per 100,000 for the period 1980–1992. Rothberg's report from 1981–1985 stated the rate for this group was 11.7 per 100,000 which is nearly the same as what we report here (11.6 per 100,000). Each of these studies has a small overlap in its study period, thus there is no explanation for a rate discrepancy of this magnitude other than an artifactual difference created by changes in the official racial-ethnic classification scheme, or a flood of servicemembers changing their racial-ethnic category, which is permitted. The overall USAF rate reported in this study increased by about 1 suicide per 100,000 since those earlier reports, a burden shared relatively equally by all socio-demographic groups.

The lack of any significant crude rate differences among age categories is similar to civilian suicide patterns for the military-relevant age groups for 1990–1997 (CDC 1999a). The crude U.S. age-specific rates are as non-generalizable to both sexes as are the USAF crude measures, as the sex-specific patterns are similar between the two populations. Age-specific suicide incidence rates for males in the general U.S. population were about twice as high as USAF male rates during the period, even after age adjustment (U.S. Army Medical Surveillance Activity (ASMA) 1999). Female rates fell within one percent of each other and increased gradually in both populations across the age groups, although the USAF female rate increased more rapidly with age (ASMA 1999). The flatness seen in the pattern of USAF suicide rates across age categories does not hold for the *absolute* incidence of suicides, as nearly 70 percent of the suicides occurred in the under-35 age group.

Specific Means of Suicide

The role of guns in USAF suicides is consistent with previous findings by Rothberg and McDowell (1988) on USAF suicides, and Helmkamp (1995) on all-military suicides, both reporting that 61 percent of male suicides were committed with firearms, while we report 59 percent. The military female percentage, too, is relatively unchanged, 55 percent in Helmkamp's paper and 53 percent in our study. The U.S. all-age percentage for female gun-related suicides in 1980–1991 was 43 percent (Helmkamp 1995). Then, as now, the female all-military and USAF-only gun-related suicide percentages were substantially higher than U.S. percentages. The Navy appears to be the exception to this pattern, as the percentage of female firearm-related suicides in that service branch for 1983–1995 (41 percent) was about the same as it was in the general U.S. population (39 percent) (Hourani et al 1999). Females in the military likely have greater familiarity with guns than civilian females, so perhaps that familiarity increases private gun ownership among USAF females or within USAF families. If so, guns may become a weapon of convenience as it has been for males both in the USAF and in the general U.S. population. It has been shown that the presence of a firearm in the home is a major situational factor in suicide deaths (Moscicki 1994).

Non-gun means for committing suicide were more commonly used by older, higher-ranking servicemembers and females. Unequal access to firearms is probably not the reason for this finding, as military personnel generally have both the financial and legal means to purchase and own a weapon. Gender differences in *socialization* may play a major role. According to this theory, there are gender differences in culturally acceptable self-destructive behaviors. Men are theoretically more likely to use more lethal means like firearms or hanging because these methods are considered "masculine" (Moscicki 1994). Females, on the other hand, are more likely to be suicide attempters since they use less-lethal, more "feminine" means (Moscicki 1994) such as poisoning. The positive relationship between USAF female suicidal gun use and rank suggests that this type of socialization, acquired in their pre-military days, dissipates as females progress in rank. This effect was not as strong in the analysis by the five

age categories; therefore, rank probably best represents the *military* socialization that occurs as one's military career advances, and which may replace "civilian" socialization to some degree. The explanation for the younger female junior officer group (O1–O3) keeping in line with this rank-based trend is that, like males, most have had four or more years in a male-dominate military environment before commissioning. This also explains why age is a less competent proxy for this military socialization. This conditioning period may have been in the USAF Reserves Officer Training Corps (AFROTC), a military academy, or from previous enlisted service. Many of that latter group become officers through Officer Training School, and they bring many years of their enlisted military experience with them. Generally, only medical, legal, and chaplaincy officers receive direct commissions and, as a result, do not go through one of those longer-term training programs above (although some have). Moscicki's review (1994) offers other possible explanations for gender differences in behaviors, but only the socialization theory is supported by our findings.

Similar differences in means-specific rates by sex and corps are likely explained by the discussion above. Proportionately, more males are in the enlisted corps and more females are in the officer corps (USAF Personnel Center 1999), thus a male-preferred means is apparent in the enlisted suicide rates while female preferences have a greater influence on officer rates. In the case of drugs and medicaments, this mechanism carries a strong female preference regardless of corps membership.

The percentage of suicides for which a drug, alcohol, or depressive condition was listed as a contributing cause of death (2.9 percent) was lower than expected, and this figure is undoubtedly much lower than the true alcohol-related proportion. In a review of the most recent literature, Moscicki (1997) estimates that 90 percent of completed suicides in all age groups are associated with mental or addictive disorders, and agreeing with others (Rich et al 1986; Shaffer 1988) that a psychiatric disorder is a necessary condition for suicide to occur. A USAF study (Rothberg and McDowell 1988) used data from the USAF Office of Special Investigations to conduct psychological autopsies on five years of suicides ($n = 322$), on conditions that existed

prior to the suicide. This study reported 4.0 percent suffered from a psychosis (the ICD-9 coding system includes alcohol-related conditons under psychosis), but did not discuss this issue more specifically. Those investigators neither reported nor discussed forensic/investigation data, which could have contributed information about alcohol or drug use at the time of death. Pollock et al (1987) assessed the validity of death certificate information for alcohol-related mortality in a follow-up study of male U.S. Army veterans. A medical panel used law enforcement reports, autopsy reports, hospital records, and other information to independently code the underlying and contributory causes of death in this cohort. Deaths were defined as "alcohol-related" if either causal category received ICD-9 codes for alcohol. The medical panel found that 20 of the 60 suicides were alcohol-related, but the death certificates failed to specify any to be related to alcohol. The discrepancy in reporting alcohol-related mortality is due to the omission of blood alcohol testing information on the death certificates in injury-related cases (Pollock et al 1987) which, if present, would be properly coded by nosologists. We suspect that a similar proportion of the suicides in our study is alcohol-related.

Occupation

Suicide rates by occupational category are similar to Helmkamp's (1996) findings in which aircraft maintenance, avionics, and security enlisted specialists each had elevated, but statistically insignificant, occupational rate ratios for suicide compared to the USAF enlisted force in general. Our rates were based on broad occupational categories, while Helmkamp's denominators were specific subgroups, yet our estimates were as imprecise as his. Still, our findings are consistent with those findings, which portrayed those groups above as having elevated rates of suicide. Helmkamp's study period covered 13 years (1980–1992) while our rates are based on a five-year period (1994–1998); so, the likelihood of finding any significant rate differences among occupational sub-groups was low. We decided against acquiring denominators for the various subgroups given the statistical circumstances.

Conclusion

Early data suggest that the USAF suicide prevention program may be successful. Better data, such as we have used from the AFMR, will be needed to validate the program's impact and to ascertain the mechanisms behind the suicidal upswing in the 1990s. Program effectiveness metrics should include sex- and corps-specific suicide rates (vs USAF crude rates) to ensure that the program's benefits are distributed equitably. This prevention program should continue to be monitored as the other services adopt the program. Program effectiveness may be (in)validated by the before-and-after comparisons as each service branch institutes these suicide prevention measures at different times. Further exploration of the socialization theory is needed to see if current program elements can address that issue, which should include a gun safety component.

The sex and rank category statistical interactions defy simplistic bivariate presentation of suicide rates as may commonly be seen. The most basic answer to rate-based inquiry outside the context of race is "it depends". Answers to questions regarding USAF suicide rates should come from stratified tables or from multivariate adjustment, not crude rates.

Special attention in the USAF's suicide surveillance system should be given to enlisted security specialists, aircraft mechanics/avionics specialists, and enlisted medical technicians. Each group surely has unique stressors and convenient access to different means or instruments of suicide.

Death certificate multiple-cause information on suicides is an improvement over the often-used Casualty information, but still provides insufficient information to assess alcohol's role in suicides or to acquire information on the specific types of guns used in suicide. The AFMR, currently a prototype (or pilot project), should be "copied" at the DoD level to use in conjunction with Casualty data and the suicide surveillance information. Casualty data remain valuable in order to acquire occupational and other information not annotated on death certificates.

Additional research is needed which would enable medical and mental health personnel to identify individuals or cohorts at particularly high suicidal risk: a predictive model with good discriminatory power. Data other than death certificate information will be needed, given the limited information that those documents convey. The official certification of behaviors like alcohol abuse which may have contributed to suicidality appears to be incompletely documented at death, but forensic information may provide those details. The USAF's new suicide surveillance system will eventually deliver information on which primary and secondary preventive measures may be applied; however, additional sources of information will be needed for research purposes until that information source has collected sufficient data. Many DoD administrative data systems (e.g., hospitalizations, personnel, safety mishap investigation) acquire data which may provide more insight on the mechanisms of Air Force suicides. Socio-demographic risk factors seen here are useful in monitoring the effectiveness of suicide prevention policies, but are only the starting place for information on which to base those policies.

Table 1. Crude USAF suicide rates by sex, race, rank category, and age, USAF 1990–1998

	MALE		FEMALE		TOTAL	
	Incidence	**Rate** *	**Incidence**	**Rate** *	**Incidence**	**Rate** *
Total†	450	13.5	30	5.0	480	12.4
Race						
White	374	14.4	26	6.2	400	13.2
Black	48	10.7	2	1.5	50	8.6
Other	26	13.0	2	4.8	28	11.6
Rank category						
E1–E5	291	15.5	17	4.2	308	13.5
E6–E9	124	16.8	2	2.4	126	15.3
O1–O3	20	3.4	8	9.9	28	6.2
O4–	13	5.0	3	9.5	16	5.5
Age category						
18–24	136	14.9	6	2.6	142	12.4
25–34	195	13.3	14	5.6	209	12.1
35 –	119	12.6	10	8.1	129	12.1

* Rates expressed in suicides per 100,000 person-years

† Total includes 2 suicides not included in the strata below due to missing information on either rank or sex

Table 2. Poisson adjusted suicide rates per 100,000 person-years: most parsimonious model with sex, corps, and race terms with interactions, USAF, 1990–1998

	MALE		FEMALE	
Race and rank categories	**Incidence**	**Rate * (95% CI)**	**Incidence**	**Rate * (95% CI)**
White				
Enlisted	346	17.1 (15.4, 19.0)	17	4.3 (2.8, 6.8)
Officer	28	5.4 (3.8, 7.6)	9	10.6 (5.8, 19.1)
Non-white				
Enlisted	69	11.8 (9.4, 14.8)	2	3.0 (1.8, 4.9)
Officer	5	3.7 (2.5, 5.6)	2	7.3 (3.9, 13.7)

** Rates expressed in suicides per 100,000 person-years*
† Total includes 2 suicides not included in the strata below due to missing information on either rank or sex

POISSON MODEL: Parameters, coefficients & 95% confidence intervals (exponentiated):

Suicide rate = [β_0 (constant) + β_1 (female) + β_2 (officer) + β_3(fem X off) + β_4 (non-white)]

where constant = 0.000171; β_1 = 0.25 (0.16, 0.40); β_2 =0.32 (0.22, 0.45); β_3 = 7.73 (3.40, 17.60) + β_4 = 0.69 (0.54, 0.88)

$\chi^2_{(207)}$ *goodness of fit =150, P = 0.999 (excellent fit).*
$\chi^2_{(1)}$ *likelihood ratio test on the composite effect of the model interaction terms = 19.6, P = 0.000 (interactions significant to model).*

Table 3. External cause of suicide, frequency and incidence rates per 100,000 person-years, by sex and corps, USAF active duty servicemembers, 1990–1998

			Suicide Rate per 100,000			
External (underlying) cause of suicide	**Freq**	**Percent**	**Male**	**Female**	**Enlisted**	**Officers**
Guns/exposives	282	58.9	8.0	2.6	8.3	2.6
Hanging/asphyxiation	100	21.0	2.9	0.5	2.8	1.6
Gases or substances	71	14.8	1.8	1.6	1.9	1.3
Drugs, medicaments (E950.0–E950.5)	27	5.6	0.6	1.2	0.7	0.7
Solid/liquid substance (E950.7–E950.9)	2	<0.1	<0.1	0.0	<0.1	0.0
MV gas/CO† (E952.0–E952.1)*	41	8.5	1.1	0.5	1.1	0.7
Other gas or vapor (E952.8)	1	<0.1	<0.1	0.0	<0.1	0.0
Cutting/piercing instruments	9	1.9	0.3	0.0	0.2	0.1
Jump	6	1.2	0.2	0.0	0.2	0.0
Other & non-specific means	12	2.6	0.4	0.2	0.4	0.1
Total	**480**	**100.0**	**13.5**	**5.0**	**13.8**	**5.8**

* *MV = motor vehicle*
† *CO = carbon monoxide*

Table 4-A. USAF gun-related suicide incidence and rates per 100,000 servicemember-years by sex and rank category, 1990–1998

Rank Category	USAF Suicides	USAF Gun-Related	USAF Female Suicides	Female Gun-Related	Percent of Female Suicides Gun-Related	Percent of Gun-Related Suicides Female	Female Gun-Related Rate	Male Gun-Related Rate
E1–E4	209	130	7	1	14.3	0.8	0.33	10.40
E5–E9	227	133	12	10	83.3	7.5	5.32	8.59
O1–O3	28	12	8	2	25.0	16.7	2.49	2.61
O4+	16	8	3	3	100.0	38.0	9.50	1.90
USAF Total	480	283	30	16	53.0	3.3	2.64	8.04

Table 4-B. USAF gun-related suicide incidence and rates per 100,000 servicemember-years by sex and age category, 1990–1998

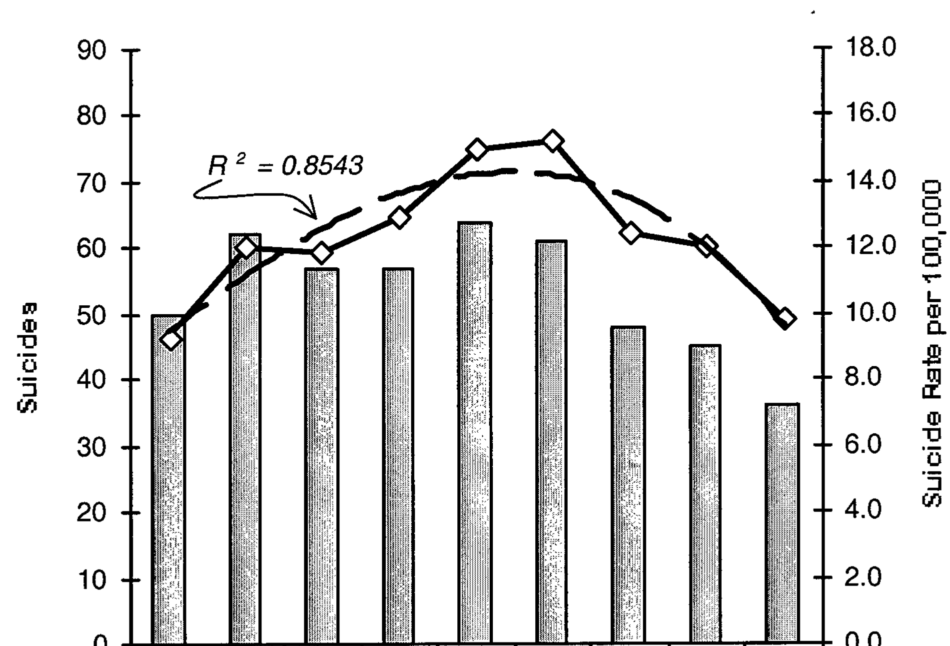
Age Category	USAF Suicides	USAF Gun-Related	USAF Female Suicides	Female Gun-Related	Percent of Female Suicides Gun-Related	Percent of Gun-Related Suicides Female	Female Gun-Related Rate	Male Gun-Related Rate
17–19	19	13	0	0	-	0	0.00	9.15
20–24	123	79	6	2	33.3	2.5	1.06	10.06
25–29	110	65	7	3	42.9	4.6	2.05	8.04
30–34	99	55	7	5	71.4	9.1	4.76	7.16
35–39	80	49	7	3	42.9	6.1	3.76	8.12
40+	49	22	3	3	100.0	13.6	6.87	5.06
USAF Total	480	283	30	16	53.0	3.3	2.64	8.04

Table 5. Suicide frequency and rate by occupational (sub)category, USAF active duty servicemembers, 1990–1998

Occupational family	Sub-group	Suicides	Suicide Rate* (95% CI)
Logistics		213	14.8 (12.0, 18.3)
	Aircraft maintenance	116	
	Communications/electrical systems	23	
Support		134	14.2 (11.0, 18.4)
	Security	44	
	Civil engineering	32	
	Communications/computers	26	
Operations		51	12.1 (8.6, 17.0)
	Aircrew operations †	23	
	Intelligence	12	
Medical		45	16.4 (11.3, 23.7)
	Clinical, non-physician/dentist ‡	18	
Other		26	9.6 (5.1, 14.1)
Unknown		9	(no denominator)

** Rates expressed in suicides per 100,000 person-years based on 1994–1998 data*
† Includes officer pilots and enlisted flight crewmembers
‡ Includes clinical nurses and enlisted medical (clinical) technicians

Figure 1. Yearly suicide frequency and rate per 100,000 person-years with least-squares line of best fit, USAF, 1990–1998



	1990	1991	1992	1993	1994	1995	1996	1997	1998
Suicides	50	62	57	57	64	61	48	45	36
Rate (USAF)	9.3	12.0	11.9	12.9	15.0	15.2	12.4	12.0	9.8

Figure 2. Yearly USAF suicide rates per 100,000 person-years illustrating differing patterns between enlisted and officer personnel, 1990–1998

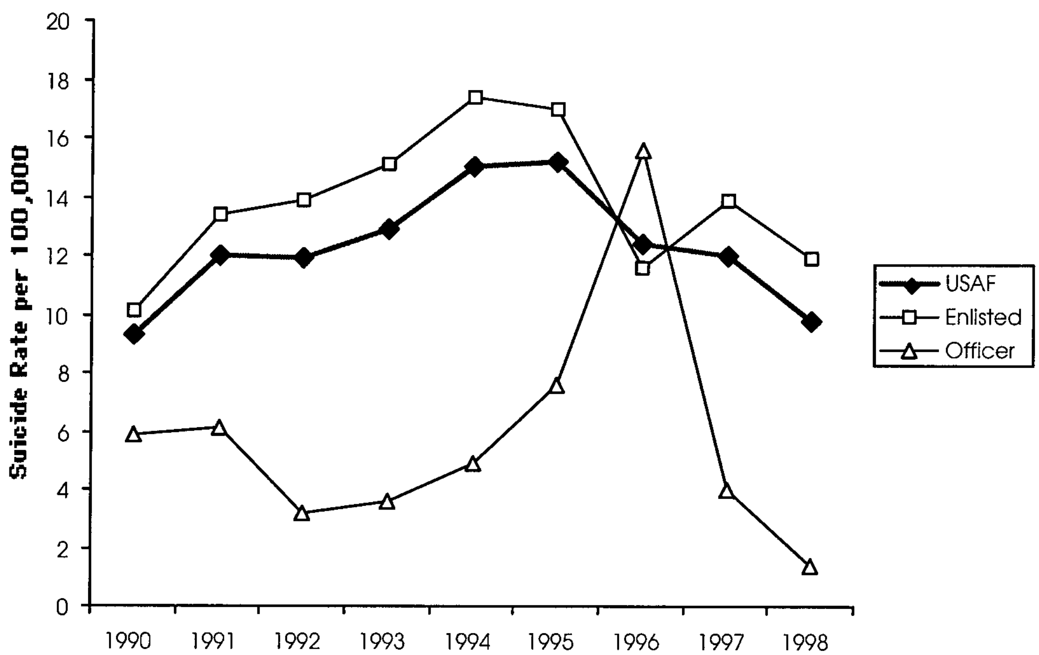


Figure 3. Suicide burden and sex-specific suicide rates per 100,000 person-years by age group, USAF 1990–1998

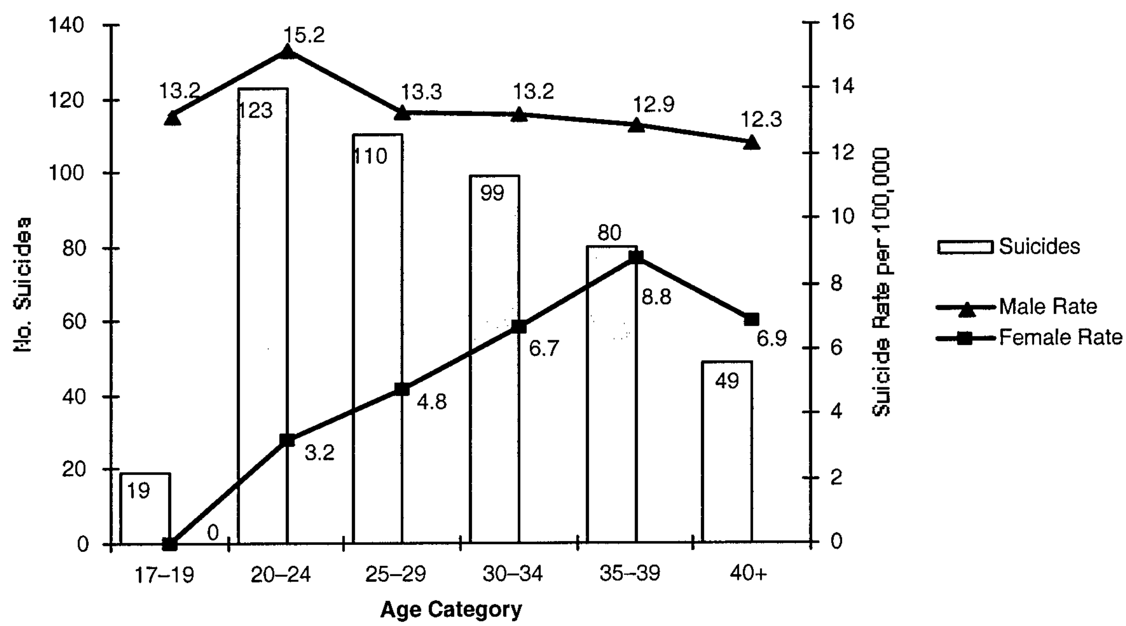
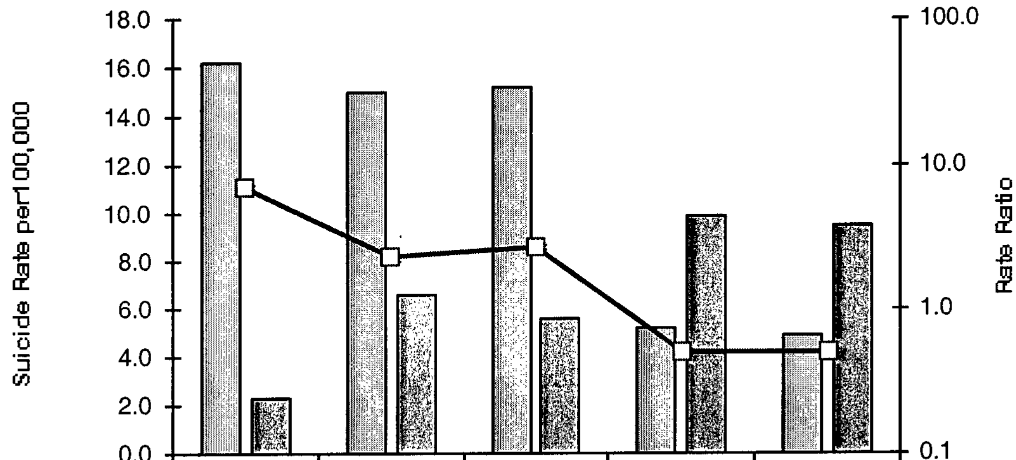
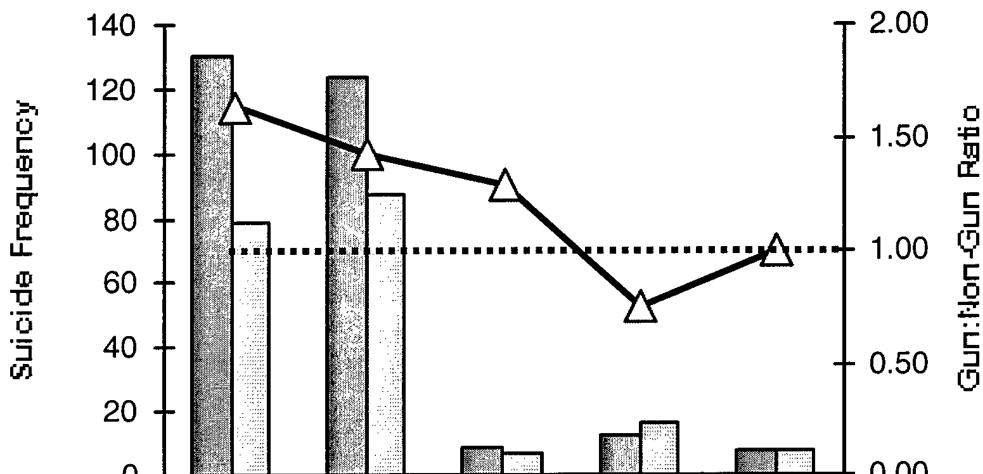


Figure 4. Male and female suicide rates per 100,000 person-years and rate ratios, by rank category, USAF 1990–1998



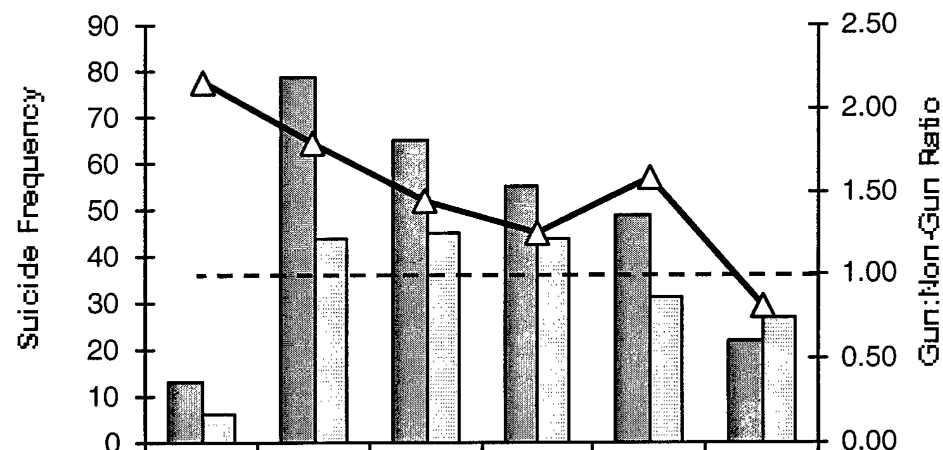
Rank Category	E1-E4	E5-E6	E7-E9	O1-O3	O4+
Male Rate	16.2	15.0	15.2	5.2	4.9
Female Rate	2.3	6.6	5.6	9.9	9.5
Rate Ratio	7.1	2.3	2.7	0.5	0.5
Rate Difference	13.9	8.4	9.6	-4.7	-4.6

Figure 5. Suicide frequency, guns vs. non-gun means with gun:non-gun ratio by rank category, USAF 1990–1998



Rank Category	E1–E4	E5–E7	E8–E9	O1–O3	O4 +
Gun	130	124	9	12	8
Non-gun	79	87	7	16	8
Ratio	1.65	1.43	1.29	0.75	1.00

Figure 6. Suicide frequency, guns vs. non-gun means with gun:non-gun ratio by age category, USAF, 1990–1998



Age Category	17–19	20–24	25–29	30–34	35–39	40+
Gun	13	79	65	55	49	22
Non-gun	6	44	45	44	31	27
Ratio	2.17	1.80	1.44	1.25	1.58	0.81

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CHAPTER 4

Suicidal Activity in the U.S. Air Force, 1990–1998: A Nested Case-Control Study of Risk Factors Obtained Through Administrative Databases

Abstract

This nested case-control study examined several proximal and prodromal factors for statistical association with suicide (n = 502) and intentionally self-inflicted injuries ("attempts", n = 1,204) in the active duty USAF cohort during 1990–98, and to develop event prediction models. "Exposure" and socio-demographic information came from administrative databases. Controls were randomly selected from the USAF risk-set at the time of event. Multivariate unconditional logistic regression models were fitted on both case-control series to estimate odds ratios (ORs), controlling for several socio-demographic factors and observation time. Cases in each series had higher incidence of both mental health hospitalization (OR = 16.0) and injury hospitalizations for all high-frequency external causes, particularly in males. A previous suicide attempt was a risk factor only for attempts (OR = 13.1). Current overseas assignment was protective (OR = 0.7) in completers, but a risk factor (OR = 1.3) in attempters. Recent deployment was protective, but only in attempters (OR = 0.5). Attempts, but not suicides, clustered by time and base. Attempters were more likely than their controls to have been exposed to (para)suicide in the past 0–7 days (OR = 3.6), the past 8–30 days (OR = 2.6), and the past 31–90 days (OR = 2.1). Prediction models for completers and attempters correctly classified over 82% of subjects but generally lacked discriminatory power.

Introduction

Background

The U.S. Air Force (USAF) and the other military service branches experienced a sustained increase in the rate of suicide in the first half of the decade of the 1990s (Helmkamp 1995; Helmkamp and Kennedy 1996; Centers for Disease Control and Prevention (CDC) 1999). Suicide, while still relatively rare at a rate of 12.4 per 100,000 servicemember-years during 1990–1998 (Copley and Smith 2000b) remained the military's (and the USAF's) third leading cause of death (Helmkamp 1995). USAF officials initiated a suicide prevention program in 1997 which targeted command awareness, social support mechanisms, and restructuring of mental health services to improve access and to remove institutional stigmatization associated with using these services. USAF also established a central surveillance database for fatal and nonfatal self-inflicted injuries (CDC 1999). Suicide rates have declined significantly after the implementation of the policy, yet a causal relation between the decline and the program has not been established conclusively, nor have the components responsible for the decline been identified (CDC 1999). The information needed to identify those components is currently limited. The collection of epidemiologic research on military suicide and suicide attempts is overwhelmingly of the descriptive type. Analytical studies using a population-based comparison group are needed to ascertain risk factors to target efforts beyond the current general across-the-board prevention measures. This analytical study provides key information for prevention which was previously unavailable.

As in most other populations, suicide *attempts* appear to be a far more frequent event in the USAF than completed suicides, with a hospitalization rate (for attempt-like "intentionally self-inflicted injuries") of 81 per 100,000 servicemember-years during 1990–1998 (Defense Medical Epidemiological Database, 1999). While comparatively little is known regarding completed suicides in the military, even less is known concerning the epidemiology of suicide attempts.

Terminology

The event terms used in this study are suicide, attempted suicide, parasuicide, and suicidal events (or activity). The term *suicide*, already quite clear, is further defined below (see *Cases). Attempted suicide* and *parasuicide* are synonymous in this study as both terms encompass both true attempts at ending life and manipulative self-injurious gestures not intended to end life. We could not, with our data, distinguish between the two intent levels. When referring to the combined completer and attempter case series, we sometimes deviate from *completers and attempters*, and use *(para)suicide*, i.e., parasuicide and suicide combined, for brevity. *Suicidal activity* or *suicidal events* includes our construct of both completions and attempts, and is consistent with (para)suicide.

Study Objectives

The primary study objective is to gain insight into suicidal causal mechanisms in the military target population, manifested as risk factors. The study population is the USAF active duty population. The study aims to test hypotheses that risk factors cited in civilian studies are applicable to the military population, while quantifying the statistical relations. Findings for the general population may not be generalizable to the military due to several socio-demographic differences (CDC 1999; Rothberg and Jones 1987). Additionally, this study tests hypotheses based on existing military-based descriptive research introduced below. Our final objective is to evaluate multivariate risk factor models for prediction capability.

Selection of Potential Risk Factors

Variables for study were selected from the hundreds of routinely collected DoD administrative data elements maintained on USAF servicemembers. The variables selected from these information systems are thought to represent or operationalize those suicidal risk factors reported in epidemiologic reviews (Moscicki 1997; Moscicki 1994; Maris 1997), clinical literature reviews (Blumenthal 1988), original civilian-based research (Grossman 1993; Holmes

and Rahe 1967), military suicide research using psychological autopsy information (Holmes et al. 1998; Rothberg et al. 1988; Rothberg and McDowell 1988; Rothberg and Jones 1987) and military-sponsored behavioral survey research (U.S. Department of Defense 1995). The epidemiologic literature supports the conceptual analytical model of distal and proximal risk factors in suicide, and the hypothetical risk factors of interest are likewise placed into that conceptual framework (Table 1).

Contagion represents a somewhat controversial risk factor (Maris 1997). In a contagion model for the global USAF, suicidal activity would cluster by both time and by location. Only one U.S. military study (Hourani et al. 1999) reports suicidal clustering along both axes. A population-based study in New Zealand (Gould et al. 1994) found space-time clustering of suicide *attempts*, but did not assess completions.

Certain military assignments are hypothesized to be proximal risk factors in this study, based on scant direct evidence. Assignment to overseas locations, combat aircraft bases, and bases slated for closure each present unique stresses similar to documented stresses (U.S. Department of Defense 1995) which could manifest as proximal risk factors for suicidal behavior.

Extraneous or Confounding Variables

Socio-demographic risk factors for suicide "completers" found in earlier military descriptive studies[3] are used as extraneous, or potentially confounding, covariates[4]. These factors include being male, enlisted, white, and unmarried. An occupational cohort study (Helmkamp 1996) indicated that several occupations experienced excess suicide risk compared to the civilian labor force. Low educational attainment was established as a risk factor for suicide attempts in a study on the Norwegian armed forces (Mehlum 1990). Age is included

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[3] (Rothberg et al 1988; Helmkamp 1995; Rothberg and Jones 1987; Rothberg and McDowell 1988; Copley and Smith 2000b;U.S. Army Medical Surveillance Activity (ASMA) 1999; Hourani et al. 1999; Helmkamp 1995; Sentell et al. 1997)

here as a confounder since suicide rates ordinally increase along age categories in females. One analytical study (Holmes et al. 1998) does, however, negatively associates age with suicide *attempts*. A review paper (Moscicki 1994) provided additional socio-demographic risk factors on suicide attempters, which are predominantly female. Observation time (number of years of individual-level data) was included as a controlling variable, since we randomly sampled from an open cohort in which *time in service* varied. During exploratory analysis it was noted that controls were observed, on average, eight months longer than cases, and that males were observed six months longer than females.

Methods

Study Design

A case-control study, nested within the USAF population, is used to examine several potential risk factors for suicide and parasuicide. The entire USAF active duty population during the period 1990–1998 was sampled and used as a control group. Incidence-density (or risk-set) sampling (Rothman and Greenland 1998; Thompson 1994; Breslow and Day 1980b) enabled the effect-measure estimates to approximate the ratio of incidence rates for chosen outcomes among exposed versus unexposed members of the population, without the "rare disease assumption" (Thompson 1994). Four controls were randomly selected from each case's risk set to achieve the most efficient statistical power.

Data Sources

AIR FORCE MORTALITY REGISTRY (AFMR)

The suicide case series was acquired through a new source of mortality data, the Air Force Mortality Registry (U.S. Air Force, 1999), except for 1990 when Casualty data was used,

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[4] The term "covariate" is also referred to as "independent variable".

as the AFMR was incomplete for 1990 at the time of this study. The attributes of the AFMR are discussed in detail elsewhere (Copley, Smith, and Grayson 2000a). The hallmark of the AFMR is that is uses full *International Classification of Diseases,* Ninth Revision (ICD-9) (DHHS 1991) multiple-cause (underlying and contributing cause) coding of all death certificate information for all active duty USAF deaths. Another feature of the AFMR is the inclusion of "120-day retirees" (Copley, Smith, and Grayson 2000a). These individuals died within 120 days *after* their military retirement or, in some cases, their involuntary release from the Air Force due to prognoses of medical disability or death (medical retirement).

Defense Medical Surveillance System

Most of our demographic and exposure data was acquired from the Defense Medical Surveillance System (1999). This all-service longitudinal database is constructed from DoD corporate databases, and includes personnel data from the Defense Manpower Data Center and each service's hospitalization data. This system provided data for several variables/risk factors used in this study as well as identifying cases for the attempter series (See *Cases* below). Hospitalization information is largely based on ICD-9 Clinical Modification (CM) codes and on a sometimes problematic injury coding system unique to the military of North Atlantic Treaty Organization (NATO) countries, the NATO Standardization Agreement (STANAG 2050) (Amoroso et al. 2000; Amoroso et al. 2000). Hospitalizations resulting from mental health-injury co-morbidity receive codes in both the ICD primary diagnosis and in the STANAG code fields.

Cases

Three series of cases, "confirmed" suicides , "potential" suicides, and suicide attempts were selected. Completers ($n = 503$) were obtained through the AFMR (underlying cause within the ICD-9 E950–E959 range). Eleven of the suicides were from the 120-day retiree roster. The AFMR, in its first phase, did not provide data for 1990. Casualty data was used for that single year to identify suicides. AFMR and Casualty were found to be in excellent agreement on the manner or intent category of death (Copley, Smith, and Grayson 2000a).

The case definition for the "potential suicide" series ($n = 86$) was based on external causes of unintentional injuries with a high potential for containing misclassified or concealed suicides (Moyer et al. 1989): any death by undetermined intent (E980–E989), unintentional firearm (E922), unintentional poisonings (E860–E869), unintentional drowning (E910), and ill-defined and unknown causes of death (N797–N799).

Suicide attempters ($n = 1,204$) came from SIDR/DMSS. An "attempt" was defined simply as any hospitalization for self-inflicted injury in which death did not occur. These hospitalizations were identified in the SIDR data through STANAG Trauma Code "4" which indicates self-inflicted injury, representing our case definition. For repeat attempters, we used only their most recent attempt to avoid repeated observations on the same individuals.

CONTROLS

For each case in all three series, four controls were randomly selected from among those servicemembers who were on active duty on the date of the *case-event* (suicide, death, or attempted suicide for each case series, respectively). This was the only restriction on control selection, thus no individual was ineligible to be a control unless they were not on active duty at the time of the case-event.

DATA LINKAGE AND CONFIDENTIALITY

We used names and social security numbers to link cases and controls to exposure and demographic data files for the purposes of acquiring multi-source data. Prior to transferring the research dataset to the investigators, AMSA replaced these identifiers with surrogate identifiers which linked controls to their cases while maintaining confidentiality. AMSA securely maintains the code identifying the actual unique identifiers/study subjects.

Study Variables

DEPENDENT VARIABLES

Three dependent (outcome) variables represent three distinct case series: suicide, suspected suicide, and attempted suicide. The suicide and attempted suicide series were later grouped into a single "attempts and completions" (AC) outcome variable.

INDEPENDENT VARIABLES

Table 1 lists the study's explanatory (independent) variables, and provides a brief overview of what the variables operationalize along with each variable's rationale for inclusion, its conceptual construct, and assumptions regarding each variable's information. All hospitalization ICD-9-CM codes, including nature of injury (N) codes, are based on the principal diagnosis only.

Proximal-Prodromal Analytical Framework

Each independent variable was assigned to either the prodromal or proximal group based on how each has been shown to operate in other populations, or how they are assumed to operate in the study population. Prodromal factors (usually called "distal") include underlying psychopathological, biologic, and familial risks (Moscicki 1994). Among these, a mental health disorder is considered as a necessary but not sufficient condition for a suicide to occur (Moscicki 1997). The authors prefer to use the term "prodromal" (Mehlum 1992) rather than distal, as while the prevalence of a psychopathological risk factor may become clinically apparent at any time relative to a suicidal event, such pathology is assumed to have been "incubating" for a relatively long time period. In this context, even a recent clinical manifestation is assumed to be the result of longer-term psychopathology.

Implicit in the hospitalization-based variables is that they represent the most severe or complex clinical prevalent cases, as outpatient data was unavailable. While the disorders are often prevalent conditions, the hospitalizations are themselves measured as incidence for the

purposes of determining risk factors on which predictions can be made. Only the principal, or primary, diagnosis was used from a potential field of 16 admission codes. By convention, principal diagnoses represent the main reason for admission to the hospital. Mental health-injury co-morbidity examination was possible since injury-related hospitalizations also receive a STANAG code in addition to the ICD code for the mental health diagnosis.

Greater temporal specificity is seen in the proximal variables where their occurrence is generally constrained to within 180 days of the case-event or "current" status at the time of measurement. The proximal definition of "depression", for instance, is more clinically specific than the prodromal depiction, as we constrain the proximal version to *situational* depression occurring within the 180-day pre-event period.

"Case defining" hospitalizations—those injury-related admissions that formed the basis for selecting "attempters", or hospitalizations in which an eventual in-patient death by suicide (or suspected suicide) was recorded—were removed. STANAG trauma and injury codes enabled identification and classification of injury-related hospitalizations by their broad external cause, e.g., poisonings.

Time Since (Para)suicidal Exposure

The average temporal distance between base-specific suicidal events, or cases, (the average incidence rate) was measured and compared with that of the entire USAF population (the controls), thus event clustering by location could be assessed. The risk estimates for each *time since exposed* category measure the statistical relation with suicidality, if any, that a single event (completion or attempt) generates on a unit's cohort as post-exposure time advances.

The variable *time since exposed* (between-event times) was arbitrarily categorized into four categories: 0–7 days, 8–30 days, 31–90 days, and beyond 90 days (reference category). Exposures were constrained to a 90-day period to reduce the inherent errors in assigning case-subjects' exposure time to the correct base, as military relocations are frequent. *Time since exposure* could not be calculated for observations which were either "first events" or "first sampled" (for controls) at each base, since there were no index observations prior to the

starting period for this study. For prediction modeling, these 112 observations were assigned imputed values for *time since exposure* based on the median value for the case-control series (e.g., attempters or completers) given that the observation was either a case or control.

Statistical Analyses

All statistical analyses were performed with Stata statistical software (StataCorp 1999). Methods for unmatched case and controls, i.e., unconditional methods, were used since sampling of the population did not include matching on any variable. The computed effect-measure of association between dependent and independent variables was the odds ratio (OR), ψ. Adjusted estimates of the OR, ψ_{adj}, were obtained using the complete field of extraneous variables. Prior to this, each variable had been formally assessed and identified as a confounder in at least one of the risk/protective factor associations with (para)suicide using the *change-in-estimate* method (Rothman and Greenland 1998), with a change threshold of five percent. None of the adjusting variables in our results were collinear.

Separate multivariate logistic regression models were used to assess the covariates for independent associations with completions and attempts. Tests for effect-measure modification, or joint effects, on the multiplicative scale employed logistic regression methods recommended by Rothman and Greenland (1998) and Thompson (1994). Deviance and likelihood ratio tests were used to identify and remove any terms which were insignificant to the multivariate logistic model, using a χ^2 probability value of 0.05 as a cutoff for model significance. Cornfield 95% CIs (Breslow and Day 1980a) were computed to assess the precision, or reliability, of the point estimates. Post-estimation assessment of the models' fit to the actual data was conducted using methods given by Hosmer and Lemeshow (1989). The two final models were assessed for the predictive capability using consensus methods (Hosmer and Lemeshow 1989; Stata Corporation 1999) which advocate using developmental and validation samples from the same dataset.

Generalized estimating equations (GEE) were used to derive OR estimates for the variable *time since exposure* (to a suicidal event), as the time it took to observe the first event in our study period was correlated with how long it took to see a second event, and so on. In statistical terms, the serial measurements of the time distances between events within each unit, or at each base, were not independent of one another. GEE methods allow the effect of the exposure to vary randomly by base/unit, consequently they are referred to as random effects models.

Results

Study Sample

Sampling methods produced two series of cases and controls: completers (cases = 502; controls = 2,008), and attempters (cases = 1,204; controls = 4,816). Random sampling of controls for each case's risk set in the population produced a comparison group which strongly resembles the characteristics of the total USAF study population (Table 2).

Potential Suicide Series

Potential suicides were dropped from the analytical scheme following preliminary analysis. This series had only one risk factor in common with the completed suicide series, *any mental health hospitalization,* $\psi = 4.2$ (1.1, 15.7), data not shown. The other statistical associations within the "potential" series were generally weak and imprecise, often in the opposite direction of the other two series. Given these conditions, the investigators concluded that the field of potential cases included a significant proportion of true "accidents". Linkage back to the original AFMR data file, necessary to examine each component of the series' case definition (i.e., separate external causes of fatal injury), was not possible (See *Methods*).

Bivariate Results: Combined Suicide and Attempted Suicide Series

The majority of statistical relations, in both strength and direction, between the exposure variables and caseness held for both completers and attempters. These two series were grouped together for greater statistical efficiency into the attempter-completer (AC) series, 1,706 cases and 6,824 controls. Odds ratio heterogeneity, as determined by χ^2 tests of homogeneity (Stata Corporation 1999), is reported between these two series when present.

PROXIMAL FACTORS

Many proximal factors such as hospitalizations for alcohol problems, depression, stress and adjustment disorders, medical disorders, and unintentional injuries were strong risk factors for both suicide and attempted suicide (Table 3). Recent alcohol-related admissions were a stronger and more significant risk factor in males than in females. Assignment to a base slated for closure was positively associated with suicidal activity, albeit weakly. Current assignment to a tactical aircraft base/unit was weakly associated with suicides, but showed a minimal negative relation with attempts (Table 3).

Neither *recent deployment* (past 12 months) nor *current overseas assignment* showed an association with completed suicide after multi-confounder adjustment (Table 3). These two factors were, however, "protective" against *attempting* suicide, deployment significantly so. Assignment to the Pacific theater (not shown) was weakly associated with suicide attempts, ψ_{adj} =1.2 (1.0, 1.5) compared to personnel assigned to other overseas locations or to stateside bases, but was insignificantly protective against completed suicides. Another strong risk factor in attempters was *time since exposure to suicidal events* (Table 4) within each major organizational unit/base. Having at least one proximal risk factor was positively associated with suicide attempts, but showed no association with completions once we adjusted the estimates for confounding.

Exposure to Suicidal Acts

Using *no exposure in last 90 days* as the reference for calculation of the OR, the effect of prior (para)suicidal exposures on suicide completions was statistically unremarkable, and the adjusted OR estimates differed little from the crude estimates across the time categories (Table 4). However, the statistical effect of the exposure on attempts was significant in both the strength of the association and in the linear OR decrease (trend) as the exposure became increasingly distal. This relation remained significant even after a moderation in the estimates after multivariate adjustment (Table 4), mainly for occupational category and time (years) under observation.

The odds of a suicide completion within the first 13 weeks (91 days) after exposure to suicidal activity followed an erratic pattern (Figure 1). The smoothing (polynomial line) of the OR seen in the figure only accounts for 34 percent (R^2) of the variation seen over the 13 weeks. The relatively low R^2 is, however, heavily influenced by two data points, weeks 10 and 11, so the modeled event odds represent a reasonable simplification of the data. The inset shows that the odds of suicide increased significantly in two of the first three days following exposure to a suicidal event within the unit/base of assignment, then decreasing during the first two post-exposure weeks. The trend during Week 3–Week 10 was one of gradually increasing odds before tapering off to the reference post-90 day event odds.

The odds of a suicide attempt began to increase on the day after the (para)suicide exposure and remained elevated for several weeks relative to the *beyond 90-day* post-exposure period (Figure 2, inset). The residual effect of the exposure prevailed into the 31–90 day post-exposure period. The area to the right of each figure's *x*-axis truncation is analogous to Table 4's reference category. A log-linear line of best fit provides an acceptable model for the decline of the odds over the 13-week period ($R^2 = 0.84$).

PRODROMAL FACTORS

Medical hospitalization during the study period was more strongly associated with suicidal events in officers than in enlisted, although multivariate adjustment somewhat reduced

the heterogeneity (Table 5). A more fine stratification of this relation indicated that the risk of suicide following medical hospitalization abruptly increased at the senior enlisted category (E7–E9) and remained elevated throughout the officer grade categories, data not shown.

Female labor and delivery (LD) hospitalizations were excluded from the hospitalizations in general, and were assessed separately (not shown). Each of the seven completer series subjects with LD admissions during the period was a control, ψ undefined. In the attempter series, 20 of 26 females with LD history were controls, $\psi = 0.9$ (0.3, 2.3). Combining the two series, prior LD hospitalizations were protective against (para)suicide, $\psi = 0.7$ (0.3, 1.8).

All diagnostic categories of mental health hospitalization were strongly associated with suicides and suicide attempts (Table 5). Injury-related hospitalizations were positively associated with subsequent suicidal behavior, particularly past hospitalizations related to a suicide attempt (Table 5). However, only one completer had a history of a prior attempt. A strong statistical relation was noted between unintentional injury-related and mental health-related hospitalizations, $\psi = 5.9$ (4.0, 8.1), suggesting co-morbidity between injury- and mental health-related hospitalizations. A history of both mental health and injury-related hospitalization of either intent category increased the odds of completing or attempting suicide by over 35 compared to those with neither type (Table 5), by 18 over those with only an injury hospitalization history (not shown), and by nearly three-fold compared to those with only a mental health hospitalization history (not shown).

Male and female injury hospitalizations were positively associated with subsequent suicidal activity; however, the statistical relation was three to five times stronger in males for the three most common causes of injury hospitalizations: falls, motor vehicle-related, and poisonings (Table 6). Accidental poisonings were most strongly related to AC caseness, and the associations were remarkably consistent between the two case series (not shown). Environment-related causes (e.g., near-drowning, thermal/cold injury, exposure, lightning) was the only injury category negatively associated with caseness, but the numbers were very small.

The heterogeneity between completers and attempters in their crude relation to *any deployment* during the study period (Table 5) was more significant than what was reported for *recent deployment* (Table 3); however, multivariate adjustment removed some of the statistical disparity. Persons who deployed to the Persian Gulf War during 1990–1991 comprised 86 percent of those who were deployed during the period, and their statistical relation with both suicides and attempts was the same as with *any deployment.* The greatest crude heterogeneity was seen in *Bosnia deployment*, $\psi = 0.6$ (0.2, 1.5) for attempters and $\psi = 1.5$ (0.6, 4.2) for completers, data not shown.

Factors Having Multiple Exposure Levels

Adjusted risk estimates for the three levels of medical hospitalization, mental health hospitalizations, and injury-related hospitalizations each show positive linear trends in their relation with suicidal activity (Table 7). The threshold effect seen in the crude OR in females for medical hospitalizations becomes a significant linear trend after multivariate adjustment for confounding. Still, the highest utilization level (4+ hospitalizations) was mostly strongly associated with (para)suicide. The confounding bias in the female crude estimates resulted from gender differences in the marital status and observation periods, data not shown.

Of the 43 individuals in the study who had been hospitalized for mental health reasons more than four times (range: 0–14), all but two either attempted or completed suicide while on active duty, and one of those committed suicide within four months post-discharge from the USAF. Relative to those who had no prior mental health hospitalizations, individuals hospitalized six or more times were about 60 times more likely to have been selected as a (para)suicide case in this study. The OR estimates are generalizable to attempters and completers, and to both sexes.

The statistical relation between caseness and alcohol-related hospitalizations generated an interesting dose-response pattern (Table 7). The OR decreased when the "exposure" increased to two or more hospitalizations. Only eight persons were hospitalized

more than twice for alcohol-related conditions, and the maximum number of hospitalizations was four.

Multivariate Analysis of Independent Risk Factors

PROXIMAL VERSUS PRODROMAL EXPOSURES

Exposure to at least one proximal risk factor raised the odds of *completing* suicide only by a factor of 1.07 (0.87, 1.30), while holding the prodromal factors constant; however, the odds of *attempting* suicide increased by 2.0 (1.69, 2.35), not shown. On the other hand, the effect of any prodromal factor, holding the proximal factors constant, was relatively homogeneous between the two series, $\psi_{adj} = 2.58$ (1.94, 3.40) in completers, and $\psi_{adj} = 3.72$ (3.12, 4.42) in attempters.

COMPLETED SUICIDES

The multivariate logistic model provided an excellent fit to the data according to the Hosmer-Lemeshow (1989) goodness-of-fit test ($P = 0.92$), as the covariate patterns were compressed into eight deciles of risk (suicide probability).

Proximal Exposures

Overseas assignment, medical hospitalization, alcohol-related hospitalization, and hospitalization for reactive stress-related disorders were each independently associated with suicide (Table 8). *Current overseas assignment* and *medical hospitalization* were the only proximal covariates of interest which remained significant to the model in the presence of the *hospitalized for mental health* term. Overseas assignment showed no association with suicide in the bivariate adjusted analysis (Table 3), but became significantly protective in the presence of the other exposure covariates (Table 8). This term was also the only primary covariate negatively related to caseness in the completer multivariate model.

Prodromal Factors

The incidence of suicide was positively related to the level (ordinal category) of mental health-related hospitalization during the study period, $\psi_{adj} = 9.15$ (5.25, 16.0) (Table 8). This estimate was sensitive to six controls who had each been hospitalized for mental health or psychiatric reasons more than three times. Censoring these observations increased the crude ordinal OR to 15.4 (7.8, 30.3). An alternative binary parameterization, *any mental health hospitalization* (not shown) showed a significant "ever-never" relation with suicide, $\psi_{adj} = 11.5$ (6.4, 20.5). Specific mental health diagnostic categories of alcohol, depression, and stress were also related to caseness, but only in the absence of the *any mental health hospitalization* term.

SUICIDE ATTEMPTERS

Proximal Exposures

Eight proximal variables were significant independent risk factors for attempted suicide (Table 9). Three of these factors were nested under the *any mental health hospitalization* term and were only pertinent in the absence of that variable: alcohol-, stress-, and reactive depression-related hospitalizations. The remaining five were significantly associated with caseness regardless of the model's specifications. A (repeat) suicide attempt was eight times more likely if the individual had recently been hospitalized due an attempt-like injury, the strongest proximal risk factor. The negligible statistical association between *current overseas assignment* and attempts seen in the adjusted bivariate analyses (Table 3) became significantly positive in the multivariate model. Deployment remained statistically protective, the only exposure-related covariate showing a negative association with suicide attempts.

The random effects model for *time since exposure* (not shown) followed the trend seen in Table 9; but, the strength of the associations was not as strong as those estimates. Odds ratios were 2.67, 1.98, and 1.83 for the 0–7 day, 8–30 day, and 31–90 day periods, respectively.

Prodromal Factors

Any mental health hospitalization and *four or more medical hospitalizations* during the period were the factors most strongly associated with caseness, with ORs exceeding 20 (Table 9). The odds of caseness increased with higher utilization of medical hospitalizations, as even 1–3 such events significantly increased the risk of a subsequent suicide attempt. The disorder-specific hospitalizations for alcohol, stress, and depression were each strongly associated with suicide attempts when the higher order term (mental health hospitalization) was excluded from the model.

EXTRANEOUS COVARIATES AS PREDICTIVE FACTORS

Extraneous factors were not the primary covariates of interest from a hypothesis testing perspective; however, they were found to be valuable for predicting suicidal behavior (Tables 8 and 9). Some of these factors distinguished between completers and attempters more starkly than did several of the primary risk factors of interest. Such is the case with age, as the age distribution differed significantly between the two study outcomes (Figure 3). Sex, age, rank, and marital status were each significant covariates in both multivariate models, although they were modeled in different forms. Occupational category was not significant to either multivariate model.

PREDICTION OF SUICIDAL EVENTS

The multivariate risk factor models correctly classified 81 percent of completer series subjects and 84 percent of the attempter series subjects at the default probability cutoff of 0.50. Sensitivity was, however, low in the attempter model (30 percent) and even lower in the completer model (12 percent). Increasing the probability cutoff further reduced the sensitivity of these models, while lowering the probability cutoff reduced the models' specificity, generating an excessive number of "false positives" (i.e., incorrect predictions of being an attempter or completer). In short, the models were ineffective in discriminating between cases and controls. Developmental and validation (split) samples were constructed from the research dataset for

both multivariate models. Both developmental models provided an acceptable fit to their respective sample data. The fit of each developmental model's parameters to the validation sample data was tested, and the fit was also acceptable.

Discussion

While suicide completers and attempters were generally from different socio-demographic niches of the USAF population, the two groups shared several common risk factors. Hospitalizations for mental health disorders and injuries were related to both outcomes. Except for alcohol-related hospitalizations, the rate of both suicide and suicide attempts increased with higher utilization of hospital services. Several variances to this homogeneity of risk factors, primarily related to assignments, are discussed below.

Potential Suicides

Some "potential" suicides were probably actual suicides given the relatively strong association that series had with *any mental health hospitalization*, a strong risk factor for suicide. As mentioned above, we could not determine which of this series' external causes were most strongly related to the field of risk factors, as the linkage was broken to maintain confidentiality. However, our findings on "known" suicide completers and attempters (See Table 6) indicate that the case definition should probably have included unintentional classifications of poisonings, certain types of motor vehicle mishaps, and falls. We also recommend including *undetermined intent* injury-related deaths (E980–E089), and possibly *ill-defined and unknown cause* deaths (N797–N799), as the literature supports their inclusion.

Proximal Factors

Proximal risk factors revealed in this study have been reported in various forms previously (see *Introduction*). However, most of those findings did not come from population-based analytical studies, rather from clinical or case-descriptive reports. While those methods produced highly plausible risk factors for (para)suicide, the strength of those associations within

the population was never demonstrated. While this study examined several proximal factors, our data sources did not allow us to study some of the more commonly-found correlates cited in those earlier studies, e.g., financial and romantic difficulties, which could potentially be as common in a control group as in a case series. Our assessment of space-time clustering of suicidal events is also the first to have been done on the USAF population, and the results call for a more rigorous study of (para)suicidal contagion.

Proximal factors dominated the attempter series, suggesting that recent events or current circumstances may—when coupled with prodromal factors such as high levels of in-patient utilization or a mental health hospitalization history— foretell suicide attempts. Proximal risk factors for completed suicides were fewer, with alcohol- and acute stress-related hospitalizations serving as the most competent predictors when only recent hospitalizations are considered.

Medical Hospitalization

The statistical relation between recent medical hospitalization and suicidal behaviors could be caused by either of two mechanisms: the hospitalizations are themselves a stressful life event (poor prognosis involving life or career), or that persons hospitalized with a medical condition were also more likely to have a co-morbid and chronic mental health disorder. The limitation of diagnostic code fields to only the principal diagnosis prevented us from exploring medical-psychiatric co-morbidity. Unlike our results, no prior evidence has suggested that medical disorders are independent risk factors for suicide outside the context of depression and substance abuse (Moscicki 1997), and we assume the same relation holds for attempted suicide. Still, our finding that the longer term medical hospitalization-suicide association generally increases as rank and age increase—when the *recent* hospitalization ORs are high across *all* rank/age categories—deserves more investigation. Future studies investigating this relationship should use the entire field of diagnostic codes, as a pre-existing mental health disorder would likely be administratively entered as a lower order diagnostic code in non-psychiatric admissions.

Deployment and Overseas Assignments

Military servicemembers are screened prior to being assigned overseas or ordered to deploy, and the screening includes mental health parameters. Given that the military is already a pre-screened population, those who are deployed or assigned overseas should be the fittest of the fit. We would, therefore, expect statistical associations between these assignments and suicidal activity to be strongly negative. Odds ratios of 1.0, as observed in this study, suggest that the screening processes were not always effective in identifying and excluding individuals with increased risk of suicidal behavior. Deployment screening was apparently more successful than the overseas clearance process in screening out eventual suicide attempters; however, this screening appeared to be ineffective in filtering out individuals who would *complete* suicide in the near term (Table 3), or in the longer term (Table 5). The odds of suicide increased slightly as the post-deployment observation period was extended beyond the first six months, perhaps indicating the longer-term effects of deployment. Given the relatively high loss to follow-up in this study on a very dynamic population, it is possible that the OR would be higher if this study had included military veterans. The statistical relation was the same for the combat-operation Persian Gulf War as for the peacekeeping mission in Bosnia, thus a common stressor in deployments may exist regardless of the type of operation. Studies of the full operational deployment cohorts are warranted to study the long-term influence of those operations on suicidality.

Unlike the bivariate results (Tables 3 & 5), the results of multivariate analysis (Table 8) indicates that overseas assignment was significantly protective against suicide. That association was based on the other covariates remaining constant. In other words, the multivariate model conveniently removed the statistical effect of mental health hospitalizations from individuals currently assigned overseas.

Contagion

We see evidence of both theoretical types of contagion mechanisms, imitation and pathological identification (Gould et al. 1989); however, our statistical methods were incapable of making a definitive finding on this phenomenon.Imitation is logically more influenced by awareness of the event (publicity), while pathological identification is "fostered by the individuals' past history that may contain may points of common experience" (Gould et al. 1989). The odds of suicide and suicide attempts each increase significantly the day after the event within the unit or base. The event odds increase for another day for attempts, then gradually lower throughout the 90-day post-exposure period. These early peaks in both groups suggest short-lived imitative behavior.

The modest increase in the odds of a *completion* in the second and third month post-exposure may represent an endemic "background frequency" of suicides which operates independently of imitation. The odds of an *attempt*, however, remain elevated throughout the 90-day period relative to the *beyond 90-day* period, as the frequency gradually tapers. This propagation does not suggest imitative behavior, as we doubt that the residual effect of an on-base suicidal event would persist for that length of time. It is important to note that most of the suicidal events-exposures were attempts which, unlike completions, occur in relative obscurity.

The relatively low potential for imitation suggests that a base's or unit's organizational and psychosocial environment and degree of social cohesion may have played a significant role in sustaining the suicide attempts in younger airmen—a "base (or unit) effect". Clustering by time alone would have been insufficient to demonstrate propagation (contagion) within USAF communities since the USAF's bases/units are widely distributed. We also noted that the odds of completions begin to increase as the attempt odds start their decline, indicating a possible lag or, contemplative, period—the "identification" that some servicemembers theoretically make with their unit-level psychosocial environment. Perhaps attempt-like hospitalizations are sentinels of increasingly more serious attempts at suicide within a unit.

Unintentional Injury Hospitalization

Recent hospitalization for unintentional injury emerged from the multivariate models as an important risk factor in attempters. This implies that a significant proportion of injuries were unrecognized or erroneously-coded suicide attempts, and that injury hospitalization is a risk factor for a (repeat) attempt within the next six months. Perhaps servicemembers with other risk factors, including socio-demographic risk factors, who are hospitalized with an unintentional injury would benefit by an "exploratory" mental health consultation during their in-patient stay, just as has been suggested for alcohol screening (Soderstrom et al. 1997).

PRODROMAL FACTORS

Prodromal factors outnumbered proximal exposures as risk factors in this study, and were more strongly associated with both attempts and completions. Our study validated that most of the mental health-based prodromal risk factors found in civilian-based studies apply to our study population, thus they are likely to apply to the military in general. We also confirmed that USAF suicide completers and attempters share the same basic prevalent disorders despite their demographic dissimilarity. These results are consistent with the literature and were expected to occur. This study, however, quantified the strength and dose-response of those associations in the Air Force, which is a unique, pre-screened population. Physical and mental health entry and retention requirements are stringent, and social controls are institutionalized. The resulting "healthy worker effect" afforded an opportunity to study suicidality in a more controlled setting, free from biases imposed by various social and health inequalities.

Mental Health-Related Hospitalization

Utilization of inpatient services for mental health disorders was the most significant risk factor for both suicide and attempts, and the odds of a suicide increased dramatically in "high utilizers", those with six or more in-patient stays. Fortunately, the public health impact of mental health hospitalizations is buffered by a relatively low proportion of subjects "exposed", 14 percent. The association between suicide and mental health hospitalization is probably higher

than we report in Table 9. A sensitivity analysis (data not shown) showed that if we censored five "non-conforming" subjects with multiple hospitalizations, the OR for *mental health hospitalization* would have increased significantly. These five high consumers of hospital services were generally unmarried, white males, thus their probability of suicide was high. Their alleged eventual suicides would have been committed outside of the USAF since these "not career retirement eligible" individuals would be at severe risk of involuntary separation. Our losses to follow-up were thus at greater likelihood of committing such an act than those who remained under observation.

Except for alcohol-related hospitalizations, the risk of suicide or attempted suicide increased as the frequency of contact with medical providers increased. Multiple mental health admissions may indicate pathology for which the mental health prognosis is poor, resulting in outcomes that the severity or complexity "predicted". An alternate school of thought suggests that serial admissions indicate serial opportunities for suicide/attempt prevention which were generally missed. Many case-subjects in this study had repeated contact with medical professionals even without considering their level of *out*patient service usage, but they still experienced a negative result. A recent study of 328 Maryland physicians found that nearly one-half had contact with at least one adolescent patient who committed suicide in the previous year; however, only 23 percent reported that they frequently or always screened these patients for suicide risk factors (Frankenfield et al 2000). While our study assessed hospitalizations instead of primary care, we suspect that screening may be similarly deficient in the USAF in-patient setting.

Yet another explanation is that the positive trends in the ORs are the result of medical surveillance, or detection, bias (Szklo and Nieto 1999), at least with attempters. Should these high utilizers later incur an injury-related hospitalization, that injury may more likely be perceived as intentionally inflicted as a result of the increased contact with the health care system. The same injury without the "history" would perhaps be labeled as unintentional.

The unexpected decrease in the OR for (para)suicide at the highest level (2+) for alcohol-related hospitalizations was significant only to the attempter series, but the same (albeit weaker) effect was seen in the completer series (not shown). The drop-off in the OR is probably the result of selective military retention similar to what we hypothesize below with suicide attempters. We suspect that the persons with the most severe psychopathology—logically those who were "chronic recidivists" or prior treatment failures—were identified during or as a result of the third (or later) hospitalization, then discharged before a suicidal event could be observed.

Previous Suicide Attempts

A previous suicide attempt during the study period was a strong discriminatory factor for attempts but not for completions, as only one completer was a previous attempter. We offer an explanation for this deviance from what was expected (Moscicki 1997). Psychiatric assessment of persons hospitalized for intentionally self-inflicted injuries may have effectively discriminated between two groups of patients: those who had made frank attempts at suicide (and at high risk for another serious attempt or completion) and those who were only trying to be manipulative by "gesturing" at suicide (Rock 1988). The real attempters, mentally ill by definition and at greatest risk for suicide, would probably have been discharged from the USAF, resulting in an observation or "censoring" bias as was discussed above. The injured who were considered to be manipulators, and those who successfully concealed their suicides, likely remained in the USAF where some would eventually make another attempt. This bias is a uniquely military situation and probably explains why our results differ from that of other studies.

Intent Misclassification of Injuries

The inference that injury hospitalizations are frequently misclassified as "accidental" is strong. Using the same case definition as we constructed for attempters, Rock (1988) determined that the ratio of attempts to completions over a 10-year period in the U.S. Army ranged from 5:1 to 12:1. Civilian data report even higher ratios (Rock 1988; Moscicki 1997). Our

data reveal only a 2.4:1 ratio over a nine-year period. This "deficit" may represent the magnitude of intent misclassification.

Poisonings, in particular, have been implicated in misclassification of suicide (Rockett and Smith 1995; Allebeck et al. 1991) and we find no reason why a suicide attempt would be any less vulnerable to intent misclassification. Each of the "high risk" external causes (Rockett and Smith 1995; Allebeck et al. 1991) are significantly and positively related to suicide in this study. (Table 6 combines attempts with completions, but the completion-only associations are nearly identical in magnitude and significance). Given the evidence for injury-mental health co-morbidity, many of these injuries were undoubtedly outward manifestations of the same psychopathology. The STANAG injury coding system has no code for undetermined intent. Forced to make "the tough call" one way or another regarding intent, few would disagree that physicians would more likely code an equivocal-intent injury as accidental.

Our findings clearly indicate differential misclassification within certain external causes of unintentional injury, with male injuries more likely to be misclassified as unintentional. Female ORs are consistently lower than those of males for those external causes associated most strongly with subsequent suicide attempts or completions. Perhaps behavioral differences in males and females account for this apparent information bias, in that males may be more likely to conceal their intent while females may more freely admit their intent. The weaker associations seen with the more benign or somewhat controllable accidents such as those associated with sports and machinery/tools makes sense. "True attempters" and completers would probably choose a more lethal means, but "manipulators" may achieve their immediate goals by those less-definitive means. Some unchecked manipulators, however, likely become actual attempters or completers, causing those weak to moderate associations (Table 6). Previous evidence supports that each successive attempt is more "serious" than the one which precedes it (Goldstein et al. 1991), thus serial self-injurious acts would be increasingly lethal, and the external cause of injury would likewise change.

Having more precise information on the occupational-relatedness would help epidemiologists in ascertaining more valid estimates of the intentional injury burden. Information from forensic investigations of USAF suicides in 1981–1985 indicated that only 3.7 percent of suicides occurred while on duty (Rothberg and McDowell 1988). A determination of whether or not an injury was sustained in the workplace could then be useful for assessing intent.

Risk Factors for Attempted Suicide

Data limitations suppressed the number of predictor variables which could be studied, but several of the suicide attempt risk factors we did find were also noted in a study using data from the Epidemiologic Catchment Area (ECA) surveys (Petronis et al. 1990) in the U.S. during the 1980s. As seen in the ECA survey, our results also indicate that being female, non-Black, unmarried, having less than a high school education, and abusing alcohol are each independently associated with suicide attempts. Demographically, USAF attempters appear to be from the same risk pool as those attempters in the general population, even after mental health pre-screening. The alcohol and depression histories were, however, the only main exposure variables that we could measure which were also included in the ECA survey. ECA-based odds ratios are higher by about three magnitudes for those two exposures, but the prevalence of these conditions was self-reported "during the period of suicide attempt". Our ORs are based on the hospitalization incidence for these prevalent conditions, accounting for the OR deviation from those reported from the ECA surveys.

Study Limitations

Limitations of this study included the reliance on administrative data which limited the field of potential risk factors. Hospitalization data gave no definitive information on the actual level of intent associated with each "intentionally self-inflicted injury", thus our case definition for *attempter* included an unknown proportion of subjects who merely made suicidal gestures. Differential loss to follow-up likely biased our study results toward the null, as censoring bias precluded the observation of suicidal outcomes in the highest risk individuals. The probability of

suicide and attempted suicide in administratively censored subjects was probably greater than those who remained in the USAF cohort to be chosen as controls. Hospitalization exposures represented only clinically-apparent, relatively severe cases, not the full clinical range of those disorders, thus inflating the effect-measures. This study measured the incidence of hospitalization for specified conditions, not the incidence or prevalence of those disorders (clinically apparent or otherwise) in the population. Co-morbid psychiatric conditions could not be assessed since we only used the principal hospitalization diagnosis. Some of the proximal risk factors are not generalizable to the general U.S. population since they are unique to the military experience; some may not apply even to other military branches due to USAF-unique assignment policies (e.g., shorter deployment periods).

Study Strengths

The nested case-control study design is an efficient way to assess the statistical independence of several risk factors. The design also allowed us to use the entire case series of suicides which are relatively rare events, thus no information on case-subjects was lost. This study's relatively large sample size provided ample statistical power to discriminate between completers and attempters, and to assess potential risk factors in stratified analyses, controlling for several confounders and enhancing the internal validity of the findings The availability of well-documented population-based USAF administrative data provided extraordinarily detailed, "clean", and complete demographic and risk factor information at a fraction of the cost of primary data collection. Most previous suicide studies have relied on a clinically-based sampling frame, not population-based. Fewer yet used a control group, instead relying on case-descriptive methods. The odds ratios are, as a result of incidence density sampling of controls, unbiased estimates of the incidence rate ratio (Rothman and Greenland 1998; Thompson 1994). Hospitalization information is believed to be nearly complete as active duty personnel are seldom hospitalized outside the DoD healthcare system (Gray et al. 1996). The AFMR was a more valid source of mortality information than has been used previously in military suicide

research, particularly the presence of the 120-day retiree cohort whose injuries occurred while on active duty.

Conclusions

Case series for suicides or suspected suicides for military-related epidemiologic research should be drawn from a mortality registry patterned after the AFMR which contains detailed, coded information from death certificates. The administratively driven Casualty data underestimates military mortality, as deaths are not registered in situations where a forced medically-based retirement precedes death.. A DoD mortality registry designed specifically for epidemiologic research does not exist, but one should be developed sooner rather than later.

Psychopathologic risk factors for suicide cited in studies on the general population apply as well to the military, and represent prodromal conditions for suicides and, even more strongly, for suicide attempts. Proximal and distal and injury-related hospitalizations classified as unintentional are each a risk factor for suicidal activity. The most plausible explanation for this association is misclassification of intentional injuries, indicating that the DoD hospitalization data system likely underestimates suicide attempts and attempt-like injuries. The underestimate of attempts appears to be more severe than the under-registration of completers, particularly in males.

Opportunities for clinical intervention are being missed by not recognizing the true intent behind misclassified unintentional injuries. Public health efforts are also jeopardized by the misclassification problem, as prevention planners may be operating with faulty information regarding the incidence of both unintentional and intentional injuries. Patients hospitalized for "accidental" or equivocal intent poisonings, falls, and single-vehicle mishaps should be investigated more closely by mental health providers, particularly in non-occupational injuries and in males.

Hospitalizations in general, and mental health admissions in particular, represent opportunities to reduce suicide in the military population, either through involuntary separation

or with intervention, or both. Clinical mental health research and economic analyses (e.g., cost-effectiveness and cost-utility studies) are each needed to guide policymakers on which direction to take.

Contagion may contribute to the Air Force's incidence of attempted suicide. Imitative behavior in both completers and attempters appears may occur to a limited degree; but, it is more likely the pathological identification variant of contagion rather than imitation that caused the attempts to cluster by base and time, and for sustaining the risk over an extended period. The USAF Suicide Prevention Program's objectives appropriately target factors which should, if remedied, remove some of the underlying base-level problems which foster the contagion. Further study is needed on the issue of contagion, using cluster and time-series analyses to more precisely disentangle the two types of contagion, as each necessitates a different intervention approach. These studies should include both time and location as parameters of interest.

The screening processes for overseas assignment and deployment need to be evaluated thoroughly with regard to mental health fitness, and further research on this subject is indicated. Additional information sources (screening inputs) may be warranted to enhance screening sensitivity.

Targeted interventions and the current USAF population-based prevention activities can co-exist, and this study's multivariate risk factor models can be used with local data to plan more focused strategies. A two-tier program would provide a safety net for those who fail to respond to one level or the other. Subsequent studies on military suicide should continue to expand and explore the field of potential risk factors, building on the models presented here. These findings should also be validated in the other service branches, supplementing DoD corporate information with service-specific databases, as was used for the most recent Army suicide study (Miller et al. 2000). Separate statistical models are necessary for completers and attempters if event prediction is a study objective, as the two outcomes differ on several factors.

The use of existing administrative data is an expedient, effective, and efficient means to acquire suicidal risk factor information for suicide prevention and intervention efforts. Administrative databases that we have used here, and other emergent data systems, should be exploited for the vast amount of information they contain. Each additional data system will no doubt contribute information which can be used to understand the circumstances under which suicidal activity occurs and which sub-groups are most amenable to intervention.

Table 1. Independent explanatory variables representing potential risk factors for suicides and attempted suicides

Variable Description and Content	Variable Construct and Assumptions
Proximal Factors (All coded [0,1] unless indicated)	
Any deployment, last 12 months (i.e., within the 12 months before the case event)	Assumes USAF standard deployment period of 6 months or less, giving ~6 months post-deployment follow-up. Separate indicator variables for each deployment (Persian Gulf, Bosnia, Rwanda, SW Asia) were later combined.
Assignment location, at time of event Categories: U.S or overseas; overseas by area: Pacific/Asia (includes AK, HI); Europe; other	Adjustments to foreign environment a source of stress. Does not account for pre-assignment period of stress/anxiety.
Currently assigned to a tactical (combat) fighter base	Stresses of deployment, preparation for deployment, and combat should be higher in throughout the base population than for bases with other missions.
Currently assigned to a base on the Base Realignment and Closure Commission (BRAC) listing	Base closure may disrupt lives of long-term assignees; "custodial" or "clean-up" perception of base/members' mission may be negative; gradual disintegration of institutional support systems.
Alcohol-related hospitalization (N303.X, N305.0), last 6 months	Indicator of proximal alcohol abuse or acute intoxication; tip of iceberg for alcohol-related problems. Assumes that proximal hospitalization reflects a response to a proximal life event.
Stress- or adjustment disorder-related hospitalization (N308, N309), last 6 months	Severe clinical response to a stressful life event or environment. Assumes the hospitalization reflects a response to a proximal event.
Situational depression-related hospitalization (N309.0-.1, N311), last 6 months	Severe clinical response to a stressful life situation or environment. ICD range limited to situational type. Assumes response is to a proximal situation.
Medically-related hospitalization, last 6 months [Excludes event-defining, mental health, injury, dental (N520;N524); in females: childbirth (N650–N654) and sterilization (V25.2)].	Proximal hospitalization may indicate a stressful life- or career-threatening situation. Dental admissions were routinely used to monitor young service members who had undergone "preventive" removal of wisdom teeth or had dentofacial abnormalities.

Variable Description and Content	Variable Construct and Assumptions
Prior suicide attempt: hospitalization for self-inflicted injury (STANAG Trauma Code 4), last 6 months	"Suicide attempt-like" admission. Represents negative reaction to a recent stressful life event or situation; 26 of 27 were in attempters. No definitive indicator of intent level to exclude "manipulators".
Hospitalized for unintentional injury, last 6 months (STANAG Trauma codes other than 0, 1, or 4)	Highest measurable level of non-battle injury severity after fatal. Statistical relation with attempts/ completions indicates potential concealed or misclassified suicide attempt.
Time since exposure to base cohort (para)suicide. Categories: 0–7 days; 8–30 days; 31–90 days; >90 days	Assesses contagion effect at each USAF base, communicated via base-level psychosocial environment. Exposure includes both suicide completions (30%) and attempts (70%). Prior attempts excluded.
Prodromal risk factors	
Number of medical hospitalizations before event, any diagnosis (ICD-9 codes exclude all below) *Categorized: none, 1, 2–6, 6+; ever/never hospitalized [0,1]*	Indicator of state of health or medical history; measures utilization of in-patient services. Not constrained to *>6 months before event.* Excludes event-defining, mental health, injury, dental, and (in females) childbirth and sterilization.
Mental health (MH) hospitalization, (N290–N316; does not include N317–N319 mental retardation.) *Categorized: none, 1–5, 6+; ever/never [0,1]*	Underlying, prodromal psychopathology of relatively high clinical severity, the "tip of the iceberg" for mental health disorders. Assesses level of clinical complexity and/or mental health co-morbidity; also measures degree of hospital utilization and contact with mental health providers before event. "Event-defining" hospitalizations excluded. Assumes a recent mental health diagnosis code still represents underlying prodromal susceptibility.
Unintentional injury hospitalization *Categorized: none, 1, 2+; ever/never [0,1]*	Highest measurable level of injury severity after fatal. Potential concealed or misclassified suicide attempt of high level of intent.
Previous hospitalization for self-inflicted injury (STANAG Trauma Code 4)	"Suicide attempt-like" admissions, any time during study period. Assume that all represent underlying psychopathology regardless of proximity to event. No other information to rate level of intent.

Variable Description and Content	Variable Construct and Assumptions
Nested MH hospitalization variables: [0,1]	
Neurosis/personality disorder, any (N300-N316)	(Same as proximal for specific mental health diagnoses in ICD-9 range)
Alcohol-related hospitalization, any (N303.X, N305.0)	Alcohol dependency or abuse. Assumes N305.0 (alcohol abuse) more than 6 months distal represents a chronic, prodromal condition, not situational (i.e., is not time-dependent).
Stress or adjustment disorder hospitalization, any (N308, N309)	Represents predisposition to respond negatively to life events, or to respond "normally" to high stress load.
Depression-related hospitalization, any (N296[.2-.3,.5], N298.0, N300.4, N300.11, N301.12, N309.0-.1, N311)	Affective disorders/depression. ICD-9 range not restricted to chronic or situational depression. Assumes situational hospitalizations are indicative of predisposed susceptibility.
History of hospitalization for both mental health and injury-related diagnoses	No time constraints on hospitalizations. Injuries may be both intentional and unintentional.
Any deployment during study period	Not truly a prodromal condition, but a distal exposure that could be related with a risk factor more closely related to, or exacerbate, a causal mechanism. Separate indicator variables for each deployment (Persian Gulf, Bosnia, Rwanda, SW Asia).

Table 2. Comparison of socio-demographic characteristics between the population sample (controls) and the total study population, 1990–1998, expressed as percentages

Socio-demographic Characteristic		Population Sample (n = 6,824)	Total USAF Population (N = 3,929,062 person-years)
Sex			
	Males	84.3	84.6
	Females	15.7	15.4
Rank Category			
	E1–E4	40.0	39.4
	E5–E9	41.1	41.2
	O1–O3	11.4	11.8
	O4+	7.5	7.5
Age Category			
	17–20	4.7	4.7
	20–24	25.3	24.3
	25–29	22.3	23.4
	30–34	20.4	20.5
	35–39	16.5	16.4
	40+	10.7	10.7
Race			
	White	79.4	78.0
	Black	15.0	14.6
	Other	5.6	7.3
Marital Status			
	Single	27.1	26.5
	Married	67.4	67.5
	Other	5.5	5.9

Note: Row percentages may not equal 100% due to rounding.

Table 3. Proximal factors: Crude and multivariate-adjusted odds ratios and 95% confidence intervals for potential risk factors for suicidal activity (attempts and completions) in active duty USAF, stratifying when applicable on heterogeneous strata, 1990–1998*

	Cases		Controls					
Predictor Variables of Interest (Exposures)	**Number Exposed**	**Number Not Exposed**	**Number Exposed**	**Number Not Exposed**	**Crude Odds Ra3tio**	**95% CI**	**Adjusted Odds Ratio ***	**95% CI**
Deployment, last 12 months								
Completers	15	487	63	1945	1.0	0.5, 1.7	1.0	0.6, 1.8
Attempters	15	1189	157	4659	0.4	0.2, 0.6	0.4	0.3, 0.8
Current assignment overseas								
Completers	81	421	405	1603	0.8	0.6, 1.0	1.0	0.9, 1.2
Attempters	293	911	1100	3716	1.1	0.9, 1.3	0.9	0.8, 1.1
Current assignment to tactical air combat base								
Completers	80	422	260	1748	1.3	1.0, 1.7	1.3	1.0, 1.7
Attempters	115	1089	530	4286	0.8	0.7, 1.0	0.9	0.7, 1.1
Current assignment to BRAC-listed base	112	1594	388	6436	1.2	0.9, 1.4	1.1	0.9, 1.4

Predictor Variables of Interest (Exposures)	Number Exposed	Number Not Exposed	Number Exposed	Number Not Exposed	Crude Odds Ratio	95% CI	Adjusted Odds Ratio *	95% CI
Medical hospitalization	103	1603	93	6731	4.7	3.5, 6.2	4.5	3.3, 6.1
Alcohol-related hospitalization, last 6 months								
Females	3	433	3	1065	2.5	0.5, 12.7	2.2	0.4, 11.4
Males	24	1246	6	5750	18.5	7.7, 44.0	18.8	7.5, 46.7
Hospitalized with situational depression, last 6 months	36	1670	3	6821	49.0	16.0, 150	49.1	14.8, 163
Hospitalized for stress or adjustment disorder, last 6 months	52	1654	5	6819	42.9	17.6, 104	40.3	15.8, 103
Suicide attempt, last 6 months (STANAG trauma code 4)	24	1682	3	6821	32.4	10.4, 101	28.8	8.4, 99.0
Hospitalized for unintentional injury, last 6 months	32	1674	22	6802	5.9	3.4, 10.2	5.4	3.0, 9.3

Predictor Variables of Interest (Exposures)	Number Exposed	Number Not Exposed	Number Exposed	Number Not Exposed	Crude Odds Ratio	95% CI	Adjusted Odds Ratio *	95% CI
Any proximal risk factor above								
Completers	294	208	1220	788	0.9	0.7, 1.1	1.0	0.7, 1.1
Attempters	939	265	2980	1836	2.2	1.9, 2.5	2.1	1.9, 2.5

* *Odds ratios are controlled for sex ,race, age, rank, educational level, marital status, observation time, and occupational category using logistic regression. Variables used in stratification excluded in adjustment. Unstratified analyses indicate the relative lack of heterogeneity between sex, corps, or series (completer or attempter) strata.*

Table 4. Crude and multivariate-adjusted odds ratios with 95% confidence intervals and test for linear trend for time since last exposed to suicidal activity (completions or attempts) at subjects' assigned bases and subjects' own suicidality (completer or attempter), 1990–1998.*

Time since last parasuicide exposure at assigned base	Cases	Controls	Crude OR	95% CI	Adjusted OR†	95% CI
Completers						
No exposure last 90 days‡	301	1320	1.0	–	1.0	–
31–90 days	89	319	1.2	0.9, 1.6	1.3	1.0, 1.8
8–30 days	50	235	0.9	0.7, 1.3	0.9	0.7, 1.2
0–7 days	20	113	0.7	0.5, 1.3	0.8	0.5, 1.3
					Score $\chi^2_{,1}$ (trend) = 0.0, P >0.99	
Attempters						
No exposure last 90 days‡	500	3108	1.0	–	1.0	–
31–90 days	279	892	1.9	1.6, 2.3	1.7	1.4, 2.0
8–30 days	217	505	2.7	2.2, 3.2	2.3	1.9, 2.8
0–7 days	159	236	4.2	3.3, 5.3	2.9	2.2, 3.7
					Score $\chi^2_{,1}$ (trend) = 128.7, P <0.01	

* *63 completer and 49 attempter series "first event" or "first sampled" subjects at each base are excluded.*
† *Odds ratios are adjusted for sex, age, rank category, educational level, marital status, occupational category, and observation time (years) using logistic regression.*
‡ *This level of exposure may be considered as "exposure occurred beyond 90 days" for most subjects.*

Table 5. Prodromal factors: Crude and multivariate-adjusted odds ratios and 95% confidence intervals for potential risk factors for suicidal activity (attempts and completions) in active duty USAF, stratifying when applicable on heterogeneous strata, 1990–1998*

	Cases		Controls					
Predictor Variables of Interest (Exposures)	**Number Exposed**	**Number Not Exposed**	**Number Exposed**	**Number Not Exposed**	**Odds ratio**	**95% CI**	**Adjusted Odds ratio***	**95% CI**
Ever hospitalized, medical								
Enlisted	140	1468	459	5075	1.1	0.9, 1.2	1.2	1.0, 1.5
Officers	20	78	100	1190	3.1	1.8, 5.2	2.5	1.4, 4.5
Mental health hospitalizations:								
Any mental health	236	1470	68	6756	15.9	12.1, 21.0	16.9	12.7, 22.7
Psychoses	60	1646	8	6816	31.1	15.1, 64.0	36.1	16.9, 77.1
Neuroses	201	1505	63	6761	14.3	10.8, 19.1	14.7	10.9, 20.0
Stress- or adjustment-related	80	1626	17	6808	19.7	11.7, 33.2	20.1	12.1, 33.4
Alcohol-related	70	1636	36	6788	8.1	5.4, 12.1	9.0	5.9, 13.1

Predictor Variables of Interest (Exposures)	Cases		Controls					
	Number Exposed	Number Not Exposed	Number Exposed	Number Not Exposed	Odds ratio	95% CI	Adjusted Odds Ratio*	95% CI
Depression-related								
Enlisted	74	1534	18	5516	14.8	8.9, 24.7	16.6	9.8, 28.2
Officer	11	87	1	1289	163.0	26.6, –	118.0	14.9, 945
Injury-related hospitalizations								
Any unintentional injury, ever	84	1622	136	6688	2.5	1.9, 3.4	2.8	2.1, 3.7
Previous suicide attempt, ever	35	1671	3	6821	47.6	15.5, 146	43.5	13.1, 145
Ever hospitalized for both mental health and injury	52	1654	6	6818	35.7	15.7, 81.4	30.4	11.2, 82.5
Deployment during study period, any location								
Completers	67	435	210	1798	1.3	1.0, 1.8	1.2	0.9, 1.6
Attempters	59	1145	495	4321	0.4	0.3, 0.6	0.7	0.5, 0.9

** Odds ratios are controlled for sex ,race, age, rank category, educational level, marital status, observational time, and occupational category using logistic regression. Variables used in stratification excluded from adjustment. Unstratified analyses indicate the relative lack of heterogeneity between sex, corps, or series (completer or attempter) strata.*

Table 6. Crude associations (odds ratios) and 95% confidence intervals between unintentional injury hospitalization and subsequent suicidal activity, by broad external cause of injury and sex, 1990–1998

External cause of injury hospitalization	Cases	Controls	Crude Odds Ratio	95% CI
No hospitalization	1623	6689	1.0	–
Environmental	1	6	0.7	0.1, 5.8
Other*	1	4	1.0	0.1, 9.4
Sports				
Males	12	51	1.1	0.6, 2.0
Females	2	4	1.2	0.0, 5.7
Machinery, tools				
Males	4	14	1.3	0.4, 3.8
Females	3	2	3.7	0.7, -
Falls				
Males	29	31	4.3	2.6, 7.2
Females	4	8	1.2	0.4, 3.9
Motor vehicle				
Males	7	7	4.6	1.7, 12.5
Females	3	4	1.8	0.5, 7.4
Poisoning				
Males	15	3	22.9	7.1, 74.1
Females	2	1	4.9	0.6, -

** Category includes air-related (1 case, 1 control), weapon-related (0 cases, 2 controls), and water transport (0 cases, 1 control)*

Table 7. Crude and multvariate-adjusted odds ratios, 95% confidence intervals, and ordinal trend (dose-response) test for multiple-level prodromal risk factors for suicidal activity, stratifying on heterogeneous strata, USAF active duty, 1990–1998*

	Cases	Controls	Crude Odds Ratio	95% CI	Adjusted Odds Ratio*	95% CI
Medical hospitalizations, all diagnoses						
Females						
None	352	868	1.0	–	1.0	–
1–3	75	198	0.9	0.7, 1.3	1.5	1.1, 2.1
4+	9	2	11.1	2.4, 52.1	19.7	3.9, 100
						Ordinal trend (OR) = 1.8 *P*<0.01
Males						–
None	1118	5327	1.0	–	1.0	
1–3	149	427	1.7	1.3, 2.0	1.8	1.5, 2.3
4+	3	2	7.1	8.2, 73.4	8.0	1.3, 49.6
						Ordinal trend (OR) = 1.9 *P*<0.01
Mental health hospitalizations						
None	1471	6757	1.0	–	1.0	–
1-5	198	64	14.2	10.6, 19.1	15.1	11.2, 20.4
6+	37	3	56.7	17.2, 186	59.1	18.0, 194
						Ordinal trend (OR) = 13.8 *P*<0.01

	Cases	Controls	Crude Odds Ratio	95% CI	Adjusted Odds Ratio*	95% CI
Unintentional injury hospitalizations						
None	1662	6688	1.0	–	1.0	–
1	77	126	2.5	1.9, 3.4	2.6	1.9, 3.5
2+	7	10	2.9	1.1, 7.6	3.0	1.1, 8.4
					Ordinal trend (OR) = 1.6 *P*<0.01	
Alcohol-related hospitalizations						
None	1636	6788	1.0	–	1.0	–
1	41	16	10.6	5.9, 19.1	10.9	6.0, 20.0
2+	29	20	6.0	3.4, 10.7	6.3	3.5, 11.4
					Non-linear trend	

** Odds ratios (OR) are adjusted for sex, race, age, rank, educational level, marital status, observation time, and occupational category using logistic regression; variables removed from adjustment if used to stratify.*

Table 8. Final multivariate model of independent risk factors for completed suicide by exposure category with adjusted model parameters (odds ratio, standard error, probability value, 95% confidence limits, and ordinal trend tests) using unconditional logistic regression, USAF active duty, 1990–1998*

Risk Factors	Reference Category	Odds Ratio	Std Error	P>|z|	95% CI
PROXIMAL EXPOSURES					
Assigned overseas currently	Assigned in U.S.	0.69	0.10	0.01	0.52, 0.90
Medical hospitalization, last 6 months	No hospitalization last 6 months	2.90	0.93	<0.01	1.54, 5.44
Alcohol-related hospitalization, last 6 months†	No alcohol-related hospitalization	4.78	3.45	0.03	1.16, 19.69
Reactive stress hospitalization, last 6 months†	No reactive stress hospitalization	38.54	41.40	<0.01	4.67, 316
PRODROMAL FACTORS					
Ever hospitalized for unintentional injury	Never hospitalized for unintentional injury	2.56	0.68	<0.01	1.52, 4.31
Mental health hospitalization, ever; ordinal [0 = 0 hospns; 1 = 1–5 hospns; 2 = 6+ hospns]	Adjacent level (measured difference between levels compared)	9.35	2.68	<0.01	5.34, 16.39
Ever hospitalized for stress-related disorder†	Never hospitalized for stress disorder	4.46	2.93	0.02	1.23, 16.19
Ever hospitalized for alcohol-related condition†	Never hospitalized for alcohol-related condition	2.40	1.15	0.07	0.94, 6.13
Ever hospitalized for depression†	Never hospitalized for depression	3.35	2.01	0.04	1.03, 10.89

Risk Factors	Reference Category	Odds Ratio	Std Error	P>|z|	95% CI
EXTRANEOUS FACTORS					
Male	Female	0.52	0.20	0.10	0.24, 1.12
Enlisted	Officer	0.36	0.15	0.02	0.16, 0.82
Male X Enlisted	Not both male and enlisted	7.99	3.70	<0.01	3.22, 19.83
Age 17–19	Age 20–54	0.52	0.14	0.02	0.30, 0.90
Race = Black	Race = non-Black	0.64	0.11	<0.01	0.47, 0.89
Married	Not married	0.66	0.07	<0.01	0.53, 0.82

Hosmer-Lemeshow χ^2 goodness-of-fit for main model = 6.0 df = 6, P>χ^2 = 0.92 (excellent fit to actual data); number of groups = 8; number of observations = 2510

* *Adjusted for covariates in model.*

† *These terms are nested under, and colinear with, the "hospitalized for mental health disorder" term and are significant to model only in the absence of that broader term.*

Table 9. Final multivariate model of independent risk factors for attempted suicide by exposure category with adjusted model parameters (odds ratio, standard error, probability value, 95% confidence limits, and ordinal trend tests) using unconditional logistic regression, USAF active duty, 1990–1998*

Risk Factors	**Reference Category**	**Odds Ratio**	**Std Error**	**P>|z|**	**95% CI**
PROXIMAL EXPOSURES					
Time since exposed to (para)suicide, assigned base†					
31–90 days	No exposure last 90 days	2.10	0.19	<0.00	1.76, 2.51
8–30 days	No exposure last 90 days	2.53	0.27	<0.00	2.05, 3.12
0–7 days	No exposure last 90 days	3.58	0.46	<0.00	2.78, 4.60
		Ordinal trend (OR) = 1.56 *P* <0.01			
Deployed, last 12 months	Did not deploy	0.50	0.15	0.02	0.28, 0.89
Assigned overseas currently	Assigned to U.S. base	1.22	0.11	0.02	1.03, 1.45
Hospitalization for unintentional injury, last 6 months	No hospitalization of this type, last 6 months	4.15	1.54	<0.01	2.00, 8.60
Suicide attempt, last 6 months	No attempt, last 6 months	8.04	5.90	<0.01	1.90, 33.94
Alcohol-related hospitalization, last 6 months‡	No hospitalization of this type, last 6 months	5.91	3.07	0.01	2.14, 16.35
Hospitalization for stress, last 6 months‡	No hospitalization of this type, last 6 months	5.76	2.25	0.01	2.30, 32.00
Hospitalization for reactive depression, last 6 months‡	No hospitalization of this type, last 6 months	7.43	8.30	0.07	0.83, 66.32
PRODROMAL FACTORS					
Mental health hospitalization, ever	Never hospitalized for mental health disorder	20.27	3.72	<0.01	4.95, 82.25

Risk Factors	Reference Category	Odds Ratio	Std Error	P>|z|	95% CI
Medical hospitalization, ever (See Table 2 for exclusions)					
Frequency:					
1–3 hospitalizations	No hospitalizations	1.75	0.21	<0.01	1.39, 2.21
4+ hospitalizations	No hospitalizations	20.55	14.92	<0.01	4.95, 85.25
		Ordinal trend (OR) = 1.92 *P* <0.01			
Ever hospitalized for alcohol-related condition‡	No hospitalization of this type	5.83	1.68	<0.01	3.32, 10.25
Ever hospitalized for stress-related condition‡	No hospitalization of this type	5.00	1.90	<0.01	2.38, 10.51
Ever hospitalized for depression‡	No hospitalization of this type	6.12	2.66	<0.01	2.62, 14.33
EXTRANEOUS FACTORS					
Female	Male	1.67	0.14	<0.01	1.42, 1.98
Age 17–19	Age 20–58	1.73	0.21	<0.01	1.37, 2.19
Rank, ordinal: 0 = E1–E4; 1 = E5–E6; 2 = E7–E9; 3 = O1–O3; 4 = O4+	Adjacent category (measured difference between levels compared)	0.57	0.03	<0.01	0.52, 0.62
Married	Not married	0.72	0.06	<0.01	0.61, 0.84
Years of observation§ (quantitative)	One less year observation time	0.89	0.02	<0.01	0.85, 0.92

Hosmer-Lemeshow χ^2 goodness-of-fit for main model = 25.5 df = 6, P>χ^2 = 0.11 (acceptable fit to actual data); number of groups = 20; number of observations = 6020

* *Adjusted for covariates seen in model*

†*Assigned case- and control-specific median values for time since exposure to 49 subjects who were chronologically the first event/control selected at each base in this study (with no knowledge of prior exposure).*

‡ *These terms are nested under—and colinear with—the "ever hospitalized for mental health disorder" term and are significant to model only in the absence of that broader term.*

§ *Mean value for years of observation in this study = 2.6.*

Figure 1. Crude odds of completed suicide during the first 13 weeks (with first week insert) following exposure to a suicide or attempted suicide within the cases' assigned units, showing quadratic trend, USAF active duty, 1990–1998

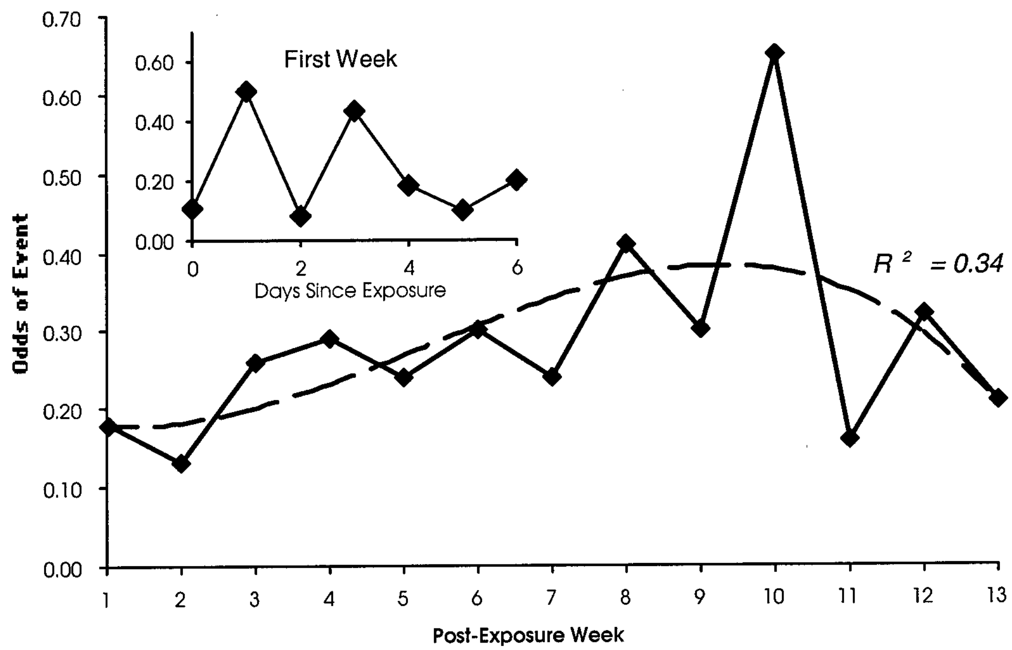


Chart uses only those observations for which the time interval from last exposure is known, not imputed values for those observations which were "first events" or "first sampled" at a base.

Figure 2. Crude odds of suicide attempt during the first 13 weeks (with first week insert) following exposure to a suicide or attempted suicide within the cases' assigned units showing log-linear trend, USAF active duty, 1990–1998

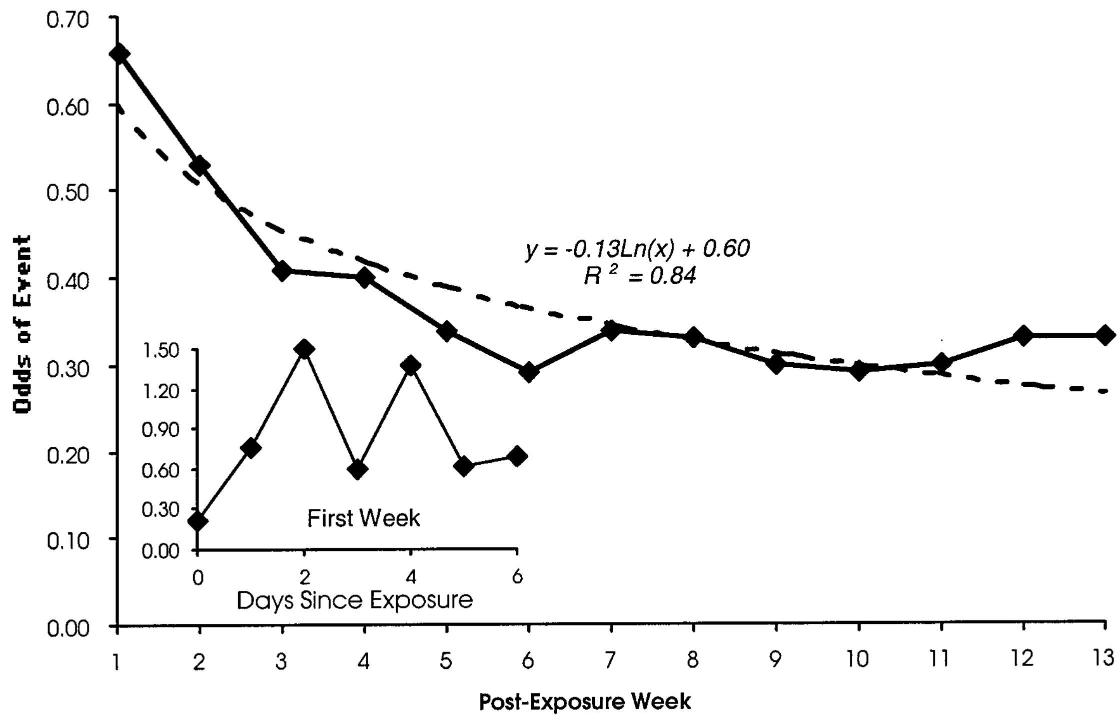
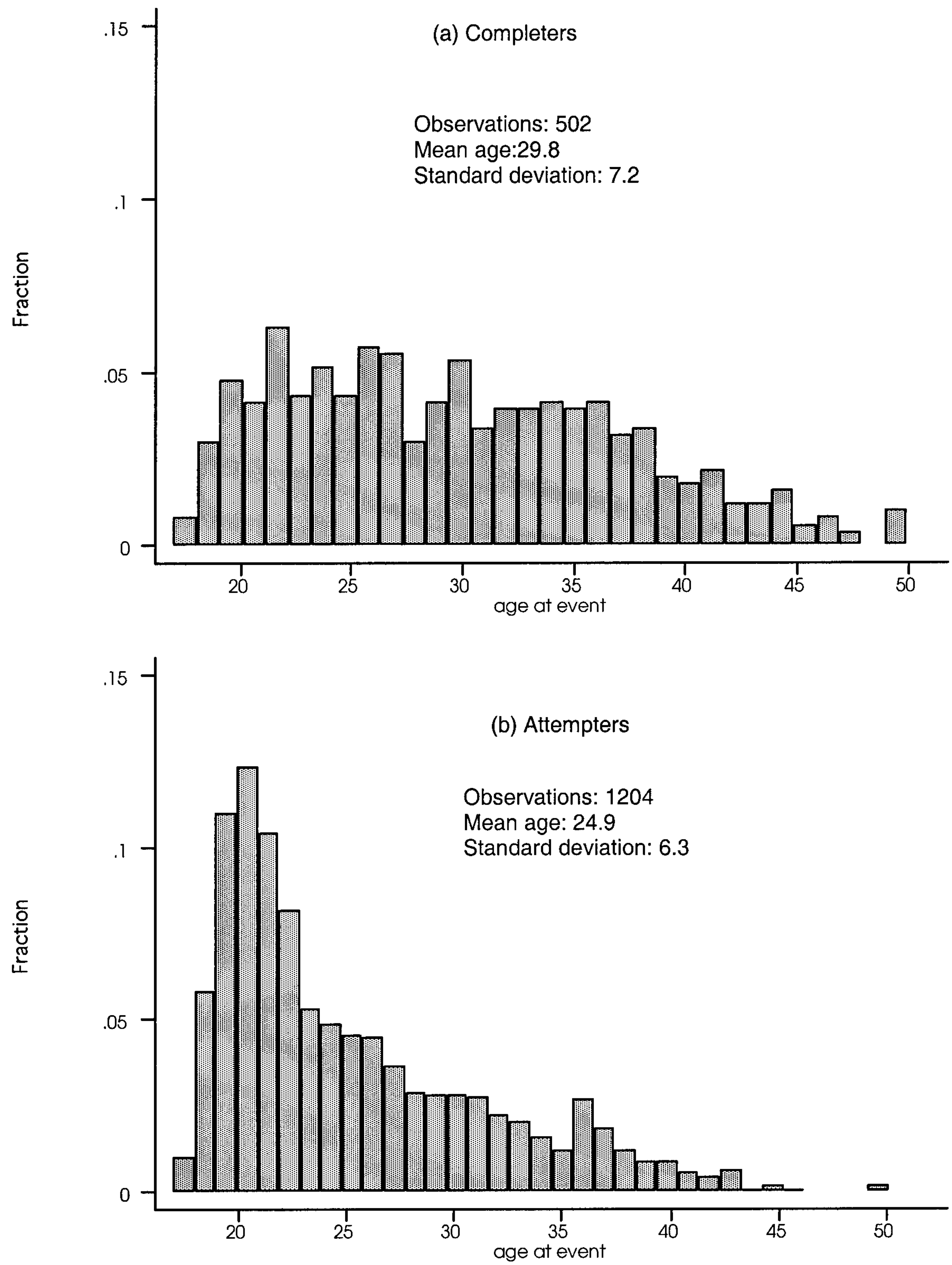


Chart uses only those observations for which the time interval from last exposure is known, not imputed values for those observations which were "first events" or "first sampled" at a base.

Figure 3. Comparison of age at death between (a) suicide completers and (b) suicide attempters, by age-specific fraction, USAF 1990–1998



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CHAPTER 5

Discussion

This research was undertaken to provide Department of Defense (DoD) and U.S. Air Force (USAF) and prevention planners insight into which segments of the population are at greatest risk for suicidal behaviors (completions or attempt-like injuries) and the exposures or prevalent conditions which statistically comprise that risk. We also wanted to accomplish those objectives using already existing administrative data and, if available, existing research data. Our reason for choosing to use existing data was not for our own convenience, but to use data which is available to base-level public mental health officials. Using Chapter 4's risk factor models, those medical personnel could use the existent data in the context of local prevention or intervention programs. The administrative data we used is available at all military medical treatment facilities (MTFs), thus no costly and time-consuming primary data collection is necessary. To these ends, we believe our study has succeeded in providing practical information to policymakers and clinicians. Our research also validated that the Air Force Mortality Registry (AFMR) does, indeed, provide a significant improvement over the official DoD's World-wide Casualty System (WCS) for mortality information, particularly on injury-related deaths. The AFMR is thus a model on which a DoD-wide system—justified by our findings—should be based. Conversely, Casualty data was found to be unreliable for injury or suicide prevention efforts. Not only was the specificity of the mortality information low, but the Casualty information underestimates mortality among all manners of death.

Reliance upon administrative data for epidemiological research may seem peculiar to some who are unfamiliar with the military; however, these information systems are truly population-based, and the military routinely and systematically collects data on its

servicemembers on nearly all aspects of their existence. Medical care is free and every person has, in theory if not practice, equal accessibility to the medical care system (Gray, Coate, Anderson et al. 1996). Each service has a centralized hospitalizations and personnel database in which an enormous amount of information is collected and maintained. Until recently, none of the military services had a central mortality registry which provided information similar what the National Center for Health Statistics (NCHS) maintains on the general U.S. population; however, the USAF now has the AFMR. Other administrative information systems have been developed as well; however, their existence is too brief to have contributed information to these studies. Future suicide research will no doubt benefit by the addition of ambulatory care, health risk appraisal, and suicide surveillance information to the mix.

We felt that "the time was right" to study USAF suicides, given the increase in suicidal activity during the 1990s that some have labeled as an epidemic. The military had, at the turn of the decade, entered a new era in military doctrine as introduced in Chapter 3. The post-Cold War era introduced new stresses into military life. Any previous research (as scant as that was) could not have measured the impact of these new potential risk factors. Suicide's high death toll during this period provided more subjects to study, increasing the power of our analyses to find risk differences between groups who were and were not "exposed" to certain factors.

This discussion which follows emphasizes methodological issues which impact the validity of our findings, both internally to the USAF and to the general population. Relevant topical issues were largely covered in the individual chapters; however, some would be expounded upon here.

Chapter 2. Air Force Mortality Registry vs Casualty: Determining the Most Valid Suicide Case Series

This study was fortunate to have two potential sources of mortality information for developing our suicide case series. The first order of business was to ascertain which of

the two sources would produce the most valid suicide case series for our planned case-control study of suicide risk factors. We also wanted to take advantage of this side-by-side comparison opportunity to assess agreement and validity issues for the complete field of injury deaths. The study found that the two sources disagreed on whether or not some deaths were a suicide. Obviously, if a death was not classified a suicide, it had to be classified into another intent category, thus an all-injury perspective allowed us to assess discordant classifications. Another finding was that some suicide deaths were in the AFMR but not in Casualty due to the administrative nature of that source's data. This will be discussed more below.

We also wanted to measure the contribution that an NCHS-like (Centers for Disease Control and Prevention (CDC) 1997) mortality surveillance system would make to the military. How does the incremental gain in information compare to the cost to maintain a mortality registry, using the AFMR as a prototype? The answer would determine whether or not we could recommend a mortality registry for the entire military. This study documented that the gain in knowledge was substantial, and well worth the $250,000 investment to create the first decade of mortality data. Only nine years of AFMR data was used since the demonstration phase was not complete at the time our study began.

No previous study had E-coded the two-part Casualty information either to the level that we did, or included as many years of data. This is also the first study to use the AFMR, and obviously the first study to compare the two sources of mortality information side-by-side. The most succinct summary of this comparison is that AFMR offers twice the E-coding precision that we were able to derive from the Casualty system's Report of Casualty, DD1300. Sixty-five percent of the AFMR's E codes were precise (coded to the most precise level that the ICD-9 coding scheme allows), while only 34 percent of the Casualty-derived E codes were precise. On the other end of the qualitative scale, the AFMR only listed 13 deaths for which a non-specific code was entered while Casualty information generated 95 non-specific E codes from the same set of deaths.

An inspection of Table 2 of Chapter 2 shows that for the vast majority of paired codes/deaths in which one source was qualitatively superior, the less-precise code came from the Casualty information. Sixty-four "accidents" on which Casualty information produced "unspecified external cause" E codes were assigned more precise E codes in the AFMR. More important for this series of studies on suicide was the finding that the qualitative inferiority of Casualty information resulted in low surveillance sensitivity for suicides with specific underlying/external causes. This lack of sensitivity was most notable in gun-related suicides at the four-digit level of coding which specifies the exact type of firearm used (e.g., handgun, shotgun, military weapon, etc).

AFMR's ICD-9 codes came directly from the death certificate information; Casualty-derived codes were derived largely from information from DD1300s which are a *transcribed* version of the original death certificate. A weighted kappa for the qualitative agreement of 0.42 at the ICD-9 four-digit level indicated that, after looking at the same death certificates, the two mortality data systems are only in "fair agreement" on the specificity of the information contained on those certificates. While a certain degree of disagreement between our codes and the AFMR nosologists' codes is expected, one would think—given that each system looks at the same field of death certificates— that they would at least contain information of the same level of specificity.

Evidence was found which supported the notion that Casualty's transcription process in recording death certificate information was flawed: the Casualty technicians are diligently recording what they perceive to be the underlying cause of death from the death certificates, but the certificates themselves had likely been inappropriately annotated. The nosologists who work on the AFMR are well-trained on extracting multiple-cause (underlying and contributory causes) mortality information from the death certificates, and the use NCHS algorithms (Rosenberg and Kochanek 1995) to synthesize the multiple-cause information into a valid and reliable underlying cause of death. In many cases, the software "corrected" the mistakes that the physician made when completing the death certificate (i.e., when he/she confuses the underlying and contributory causes). In

summary, the difference in precision between the two data sources represents the magnitude of the information loss that occurs as a result of Casualty's transcription. This process does not reliably reproduce the information found on death certificates.

The Casualty system appears to have undercounted suicides by three (<1%), and misclassified four non-suicides as suicide. We are stuck with the impression that with those four cases "Casualty knows something that the death certificate cannot convey", but we failed to prove our suspicions that the internal forensic/law enforcement reports were influencing the official DoD intent category classification. The issue of the "missing" suicides does not involve misclassification; it means that these three individuals are not listed as deceased by Casualty. We speculate about the reasons for this in Chapter 2; however, a definitive answer will not surface until the AFMR and WCS systems can link and reconcile differences on who died.

We also introduced a unique feature of the AFMR, the 120-day retiree element; however, we did not include this small cohort in the side-by-side comparisons between the AFMR and Casualty data, as the Casualty system does not capture those deaths. These deaths occurred in USAF retirees within 120 days of their release from active duty. Some members of this death cohort sustained a life- or career-threatening injury (a "failed attempt") while on active duty and were involuntarily medically retired (discharged) soon thereafter. These "attempt-like injuries" would later be classified as suicides after their out-of-service death. We found 11 suicides in this cohort which were not listed in Casualty (the three discussed above not included). This finding weighed heavily in our determination that AFMR contained the most valid suicide data. In a related research effort, we found that 10 percent of active duty USAF injuries which became homicides were cases in which *death* occurred after the victim had apparently been medically retired. Again, these deaths were not registered by Casualty, indicating a systematic underestimate of mortality across all intent categories. The 120-day retirees particularly enhance the validity of the AFMR as they—if they had died immediately—would also have been listed in Casualty. We have no denominator, or population base, for the 120-day retirees since the AFMR does not

enumerate the living, thus we could not consider these medical retirements as risk factors (exposures) for the case-control study (Chapter 4).

This study concluded that Casualty information is generally not reliable for injury prevention research at the three- and four-digit level; and, the AFMR should be used for this type of research. The E-coding is superior to what we were able to derive from Casualty information, and the coding has already been done by nosologists, unlike Casualty information that requires investigators to do their own coding. Casualty information did provide some valuable information on occupation and service component (Active Duty, Reserves, Air National Guard). We also concluded that the AFMR should be our source for our suicide case series in Chapter 4's case-control study. Having a more specific external cause on all-manner injury deaths also enabled us to construct a case definition for "suspected suicides", another case series for that other study.

Chapter 3. Descriptive Epidemiology of USAF Suicide, 1990–1998

This study began with an update of suicide rate comparisons along socio-demographic lines. Earlier studies on USAF suicides covered the first part of the 1990s decade, but we extended that period through 1998. While no new findings appeared among the socio-demographic variables, our Poisson regression models adjusted the suicide rates by sex, rank, and race. This simplified the understanding of the crude bivariate rates normally seen in most presentations. The statistical interaction between gender and rank (corps) rendered bivariate crude rates for either invalid.

MULTIPLE CAUSE OF DEATH INFORMATION

This study's primary distinguishing characteristic is the use of multiple cause of death (underlying and contributory) information from death certificates, obtained through the AFMR. Rates for specific external causes (means of injury) were more detailed than in any previous study. We found significant male-female and officer-enlisted differences in the means-specific suicide rates. The rates for males and enlisted, and females and officers,

were nearly equal across all external cause categories except drugs and medicaments, a female-dominant means of suicide.

Intent Misclassification of Injury Hospitalizations

Linking this study with Chapter 4 (Table 6), we gain better insight on what appears to be misclassification of intentional injuries. Chapter 4 clearly suggests significant misclassification of intentional poisonings, particularly in males. Six of the male hospitalizations for accidental poisonings later completed suicide (not necessarily by poisoning), along with one of the females. Coming back to Chapter 3 (Table 3) we note that the male rate for suicidal poisonings is one-half that of the female rate. The index of suspicion for misclassification is bolstered by what we find in the U.S population. U.S. rates for suicidal poisonings are nearly the same until age 40, then the male rates begin to decline, while female continue to increase (Baker, O'Neill, Ginsburg, and Li 1992). In our case series of USAF suicides, 90 percent are under age 40. Do males in the USAF use poisoning only as a suicidal gesture, or are fatal poisonings being misclassified as accidental deaths? Our study could not answer that question, but the strong statistical relation between poisonings and later suicide in males implies that the latter hypothesis may be the most plausible. It has been said that the closer a person gets to killing himself, the more he should resemble a person who *has* killed himself in personal or social characteristics (socio-demographics) (Pallis and Sainsbury 1976). Suicides—like "accidental" poisonings, falls, and motor vehicle mishaps—are male-dominant, thus one has to suspect intent misclassification. This forensics issue should be investigated in greater detail using additional sources of information, including psychological autopsies or death investigation reports.

Firearms in Suicide

Firearm ownership and possession is a relevant issue to address in planning suicide prevention and intervention efforts. Firearms are the most commonly-used means of suicide in both sexes (Chapter 3, Table 3), and few servicemembers are survivors of

serious gunshot wounds (Chapter 4, Table 6, totals included in "Other" category). It is obvious that few suicidal gestures are made with guns, as the lethality and certainty associated with these injuries indicates a high level of intent. Chapter 3 (Table 4) shows that the percentage of USAF gun-related suicides which occur in females increases with rank and age, as their choice of method (and one presumes the level of intent) resembles that of males as age increases. We do not know what factors are associated with that change in *modus operandi.* Issues such as medical/mental health status, marital status, service status of spouse (civilian dependent or military), and access to weapons need to be investigated more closely for behavioral clues that may be important for suicide prevention.

Occupation

Occupational category was included in Chapter 4's case-control study as an adjusting variable due to the results seen in Chapter 3 (Table 5). While each major occupational group's suicide rate was statistically indistinguishable from the others' and not a significant suicidal risk factor in its own right, we did find occupation to be an influential confounder in our adjusted bivariate analyses. Our studies, as did Helmkamp's (1996), did not find a significant association between broad occupational category and suicide. The investigation into occupational-relatedness should continue since a large number of civilian-based studies have found wide variation by specific occupation (e.g., dentists). Official military occupational classification systems may not always be as precise or descriptive as, say, Safety Center injury report information. In the military's "other duties as assigned" philosophy, one's occupational skill code may not reflect one's actual job placement. The author has, in over 15 years of USAF service, seen several instances in which servicemembers of one occupation are placed into an unrelated (and sometimes an untrained-for) assignment for varying time periods. This situation would result in job/exposure misclassification which, if prevalent in all occupational groups, would result in a bas toward the null.

Another reason for weak associations between occupation and suicide is that these relations have not been stratified by rank. The military has hundreds of workers of specific types who are supervisors. These individuals are generally "sergeants" or officers who are generally not subjected to the same job stresses as the more junior rank-and-file. However, these supervisors fall into the same occupational category and are generally included in epidemiologic studies of occupation. Additional studies are needed to investigate this situation, preferably using additional years of information to obtain decent precision on the estimates.

In summary, this study was more detailed than any of the recent descriptive studies on suicide, as accurate multiple-cause mortality information introduced an additional layer of information. Our analytical methods were also more sophisticated than the other descriptive studies, as the stratification and adjustment schemes allowed a presentation of results that allowed a deeper understanding of the epidemiology of suicide in the USAF.

Chapter 4. Nested Case-Control Study

Rationale

Why further investigate psychopathology as a risk factor for suicidal acts? Our investigation of prodromal/distal (underlying or prevalent) factors was not redundant to civilian studies with similar motives, even under the assumption that those factors are just as valid in a military population. Besides validating that assumption, we quantified the statistical relations between prodromal factors and suicidal activity, and at a relatively high level of clinical severity which increased the validity of those clinical diagnoses. Unlike civilian-based studies, we investigated proximal military-unique exposures such as assignments and deployment.

METHODOLOGICAL ISSUES: STRENGTHS AND WEAKNESSES

Having both proximal and prodromal factors in the same models was advantageous. The "biological plausibility" of our proximal findings was sustained by the fact that we also validated that prodromal factors seen in many civilian-based studies operate in the same manner in the military world. In short, the prodromal element of our statistical models "behaved" according to currently held causal theory, thus adding credence to our proximal findings. This conforming behavior supports the notion that our models were specified correctly, thus the proximal factors we report as risk factors are equally valid in our study population as the prodromal factors.

Proximal risk factors disclosed in this study have previously been reported in population surveys, descriptive clinical studies, and studies based on psychological autopsy information. Many of these studies were conducted in military populations, but most lacked a comparison population such as we constructed, thus estimates of *relative* risk were not feasible aside from socio-demographic variables. None of the recent military studies used hospitalization data to depict proximal events. While information from other sources such as psychological autopsies are arguably the "gold standard", they are done only on deceased members. High incidence or prevalence of a particular factor in a suicide case series does not preclude the possibility that the incidence or prevalence was as high, or higher, in a control group consisting largely of living servicemembers. Psychological autopsies also exclude suicide attempters. Our study variables represented the assignment setting, not studied previously. Our assessment of space-time clustering of suicidal events is also the first to have been done on the USAF population.

We were fortunate to have access to military data, not only for the exposures of interest, but also for the extraneous variables. Unlike many of the civilian-based studies in which a population registry is unavailable, our point estimates are adjusted for a wide array of socio-demographic factors. Thus, our estimates are relatively free of apparent confounding bias and, as a result, they appear to be internally valid.

Generalizability to the general U.S. population may hold for some prodromal factors since many of those factors are not military-unique. Military assignment (deployment and overseas) findings are probably not directly generalizable to any other population. However, our findings may depict risks in the general population imposed by moving and involuntary relocation. Some of our findings in this area may not be representative of all service branches. Each service branch has its own assignment and deployment policies which affect which members are qualified for those assignments/missions and the duration of that assignment. The USAF has by far the shortest "standard" deployment period of all the services, six months. The other service branches generally deploy for 12 months, but deployments longer than that are not uncommon.

Study Design

The retrospective study design and overall methodology maintained internal validity regarding the time sequence of exposures and events. Exposures always preceded events and a proximal-prodromal cutoff placed the events into the appropriate risk factor category. The nested case-control study design with incidence-density sampling of population controls enabled each individual's control selection probability to be proportional to the individual's person-time at risk for (para)suicide. This feature allows our odds ratios to be interpreted as incidence rate ratios, an easier concept to understand.

Our sampling methods allowed measurement of time-dependent extraneous variables at the time of the case-event. As a result, we did not need to artificially "age" or "promote" controls as would be needed if they had been chosen at the beginning of the study. The control sampling plan itself produced a most representative sample of the USAF population, thus we have not introduced systematic selection bias into our study, at least on those five population parameters compared in Table 2 of Chapter 4. As a result of the sample that closely resembled the total USAF population, our nested case-control design was statistically efficient without apparent sampling bias.

The statistical adjustment for unequal observation times enhanced the validity of our findings within the attempter model (the term was not significant to the completion model), as each subject's observation time was largely a function of when the case-defining event occurred, since this was the date of "sampling". Subjects sampled soon after the 1 January 1990 observation start date had little, if any, time for exposures to occur. Subjects entering the study more distal to that date obviously had greater opportunity to experience an exposure of interest.

Categorization and Dichotomization of Continuous Data

We had no previous information on which to form *a priori* data (information) reduction schemes, so certain elements of this study were exploratory. For instance, no study had ascertained the number or level of medical hospitalizations at which the (para)suicide risk had increased (or decreased) significantly. Our efforts to locate and report effect-measure thresholds, threshold shifts, or cutpoints should not be confused with manipulating the data in order to fulfill preconceived hypotheses regarding thresholds.

Clinical Severity and Hospitalizations

Hospitalization data, although relatively limited to the more severe conditions, are collected on each individual prospectively without regard to eventual case or non-case status. Also, the SIDR is the USAF corporate inpatient data system and it covers all members with equal access to all socio-demographic groups. As a result, these data and the risk factors depicted by the data allow both complete and unbiased measurement of exposures in both cases and controls and in all sub-groups of the USAF population.

The perceived high clinical severity represented by hospitalizations ostensibly amplifies any statistical association with (para)suicide which exists at lower levels of severity, including unrecognized or undiagnosed cases. A hospitalization in the military health care system is not, however, invariably of high clinical severity. The military uses its institutions, including hospitals, to further its interests which include the health and welfare of its members, individually or collectively. Young and generally single airmen living in

USAF dormitories were summarily admitted to the hospital solely for observation following dental surgery to extract emergent third molars. Likewise, admissions may sometimes have been the result of the command's responsibility to protect other airmen (public health interests) and not necessarily related to a hospitalized individual's clinical state. Mental health hospitalizations may at times have been to remove non-normative, mission-disruptive behavior from the command, resulting in observation and subsequent diagnosis that would probably have gone unrecognized in the civilian community. The hospitalizations, then, are not exclusively severe cases as they would be in the general population. Instead, the USAF hospitalizations represent a wider cross-section of clinical severity than one generally sees in in-patient data.

Hospitalization data for certain types of injuries, particularly motor vehicle-related mishaps, may not be representative of all such admissions. Moderate to severe injuries occurring outside of the general vicinity of the base hospital, or where the base only offers outpatient services, would have been admitted to a civilian hospital and possibly not recorded in the SIDR. The existence of this bias has not been verified and, if present, the "direction" of such a systematic bias is unknown. The number of such hospitalizations is assumed to be small, but that assumption needs to be verified in future studies. We did not request data which would have identified which hospitalizations were "transfer-in" (to military hospitals), nor does ASMA maintain the "carded for record only" (CRO) data element. CROs document military deaths which do not occur as in-patients in military hospitals. Deaths in civilian hospitals, or in civilian or military emergency departments, are commonly entered as CROs.

Despite the advantages of using hospitalization data, a more refined and robust study would include outpatient-level data to examine the total spectrum of the pathological risk factors. In the U.S. Army, an estimated 20 injury sick call (i.e., urgent care, emergency department) visits occur for every one injury hospitalization (Hansen, Jones, et al. 1996). We have seen no similar estimates for mental health or medical-related conditions; however, that ratio would seem to be higher. Outpatient data systems were

activated relatively recently, and we have seen no reports documenting the quality of those data.

Use of Administrative Data

The use of SIDR as the primary source of hospitalization-based risk factor data offers both strengths and weaknesses. The SIDR is an administrative database with the usual diagnostic coding (ICD, STANAG) imperfections and limitations which create some degree of disparity between these codes and "reality". SIDR does, however, represent clinical assessments on individuals, not ecologic or self-reported information, so the content validity of our exposure variables is believed to be high, as is SIDR's completeness.

Limiting the diagnostic information to the primary diagnosis (out of a possible 16 diagnostic fields) precluded assessment of mental health-medical illness co-morbidity (Refer to Chapter 4, *Methods* for rationale). Concerns over whether we could ascertain mental health-related conditions when the primary diagnosis was injury-related, however, were largely resolved by the separate data fields in SIDR: injury (STANAG) and non-injury (ICD-9) admissions. We noted 56 admissions indicating mental health-injury co-morbidity.

The greatest weakness in not using data primarily collected for a specific research interest is that many of the variables hypothesized to be (para)suicidal risk factors cannot be studied. While survey data are subject to their own weaknesses (several well-studied biases), surveys offer limitless study variables if one is willing to live with the biases. This study could not assess those factors falling outside the scope of the administrative function for which the information system exists.

Administrative data, unlike many research datasets, are available to clinicians and planners throughout the USAF. Identification of individuals, or sub-groups of the USAF population, which harbor risk factors found in this study would be feasible as part of routine surveillance on groups with elevated risk.

USAF Mortality Registry

Our selection of the AFMR as our primary source for suicides contributed 11 additional suicides (and, indirectly, 44 more controls) to this study, increasing its validity and statistical power over what would have been achieved using only Casualty information. Persons completing suicide within four months of their separation from the military would still be "statistically affected" by those exposures (e.g., hospitalizations) and psychologically affected by those conditions (e.g., depression) which occurred during their military service. We could also argue that this type of separation from the military, frequently associated with onset/diagnosis of medical illnesses with poor prognoses, is a risk factor for suicide itself. In some cases, the suicidal event (the self-inflicted injury) actually occurred while the subject was still in the USAF. Persons with severe injuries with poor expected outcomes (i.e., death or residual disqualifying disability) are promptly and involuntarily "medically retired" according to military medical policy. While an injury-related hospitalization would be documented in SIDR, the suicide would not be registered in Casualty since the death would have occurred after separation from the USAF, regardless of whether or not the actual death occurred in a military hospital. The AFMR would, however, document these deaths if they occurred within 120 days of the medical retirement.

The AFMR also enabled us to define a case series of "potential suicides". The usual source of mortality data, the Casualty files, does not offer precise underlying causes of death as does the AFMR. This more precise cause of death information is needed to develop a working definition of misclassified suicides. The fact that our definition did not share many attributes with the "true suicides" does not diminish the potential for investigating intent misclassification using the AFMR.

The primary weakness in using the AFMR was that this source only offers information from death certificates which are also a form of administrative data. The information on the certificate is sufficient to the administration of vital statistics; however, this information cannot answer all the questions on the cause of death that an investigator

may desire (Rosenberg and Kochanek 1995). Whatever the information deficiencies, the death certificates are expertly coded in the AFMR for multiple causes of death, an advantage which should not be discounted.

Suicidal Events

This study lacked any additional information from which to specify the degree of intent associated with these "suicide attempt-like" hospitalizations, and we acknowledge that our version of "attempts" include suicidal gestures of lesser intent. Our purposeful restriction of suicide attempts to the most recent such event undercounted attempt incidence, as it negated counting those events (and their characteristics) more than once. Suicide completions and attempts were also undercounted as a result of an unintended systematic bias inherent to our study design. Some subjects were chosen as controls who were inclined to commit a suicidal act, based on their high predicted probability of (para)suicide, i.e., they had multiple risk factors in their record. Their assumed suicidal acts were not counted, either due to their military discharge or because the observation period ended (with the exception of suicidal acts committed by members of the small 120-day retiree cohort). We also speculate that mental health disorders, the strongest risk factors in our study, are a major cause for involuntary military discharge. Our reported point estimates for those risk factors—even though they are already impressive—are likely biased toward the negative (OR <1.0) to some extent as a result of the differential loss to follow-up (i.e., those at greatest risk are more likely to be discharged). This bias would also indicate that our prediction models would have, without the bias, shown greater discriminatory power.

We speculate that part of the models' difficulty discriminating between cases and controls was due to an intentional mingling of the two groups. Recall that our random sampling of controls came from the risk-set, the population at risk for suicides/attempts at the time of each event. Eventual cases were eligible to be selected as controls since they too were part of the risk-set before they became a case. This concern was, however,

dismissed after calculating the suicide rate in the USAF during the study period, 12.4 per 100,000 servicemember years (from Chapter 3). In other words, there was an average one-year probability of 0.000124 that any of the 2,008 selected controls would also be a case in our study. Even persons in the risk-set for all nine years had little more than a one-in-one-thousand chance of being selected. The linkage back to the AFMR dataset was intentionally severed for confidentiality reasons, thus we could not confirm if any cases were also selected as controls.

The above-mentioned censoring of all attempts cases prior to the most recent event (which defined this case series) biased the risk estimates for *time since exposure* toward the null. Including prior attempts ($n = 38$) would have narrowed the interval between suicidal acts, shortening the time since exposure. Our methods allowed the exposure intervals to be longer than they actually were, pushing cases back into the more distal and more "populated" exposure strata where each additional case has little impact on that stratum's odds. The additional 35 attempts in cases (but only three in controls) would have increased the number of 0–7 and 8–30 day exposures by about two percent in cases, thus any bias would shorten the exposure period in that group by about the same percentage. Shortening *time since exposure* in this manner would likely have generated a slight increase in the odds of caseness at the expense of the more distal periods (including the post 90-day reference period).

Recent exposure to a suicidal act (completion or attempt) was a significant risk factor for subsequent suicide attempts, but was less of a factor for completions. The time-space clustering in the attempters would at first seem to suggest an imitation type of contagion effect, given their typically younger age and rank. Imitation can only exist in the presence of a known act which may be copied. Suicide completions occurring in military populations are well-publicized within the tightly-knit military community, but attempts are generally not. The likelihood of imitating a relatively-unknown attempt would logically be lower than the probability of an imitation following a highly-publicized completion.

According to Durkheim (Simpson 1951), imitation is not a causal (or original) factor in suicide, as it only exposes a psychosocial environment which is the true causal factor. This philosophy suggests that the base- or unit-level effect, not contagion, is responsible for any time-clustering clustering of events on those bases. Completers of suicide following previous local suicidal exposure may already be vulnerable and "prepared" to commit their final act (Maris 1997), i.e., those suicides were inevitable.

The observed association between prior exposure to (para)suicide and subsequent suicidal acts—events which included both suicide attempts and completions as index events—probably measured the influence of an installation's psychosocial environment on (para)suicide better than had we limited index events to completions. We believe that the inclusion of attempts is a better measure of the common experience associated with pathological identification, where the contagion is "broadcast", or disseminated, to a base cohort through the psychosocial environment. Detection of this more subtle form of contagion is probably better measured by suicide attempts than completions, since the effect of imitation is largely eliminated from the epidemiologic curve. Attempts are the predominant dependent variable in this study.

Exposure Categorization

We divided risk factors into two categories, proximal and prodromal. Many of the "exposures" in both categories are prevalent conditions, particularly mental health-related disorders of relatively high severity. We did not, however, want to confine our research to estimating the prevalence of these conditions. Instead, we used the *hospitalization incidence for prevalent conditions* as hypothetical risk factors. We found that the frequency of these events significantly affected the probability of committing a suicidal act, as high utilization rates increased the (para)suicidal risk. Injury hospitalization is generally not due to a prevalent condition in most cases, at least in the relatively young active duty population; and, the frequency of these events was also positively related to the probability of committing a suicidal act. The ramifications of this result with injuries is that injury

hospitalization is not only a risk factor for suicide and attempted suicide, but probably represents a systematic misclassification bias in the information system. The incidence of intentionally self-inflicted injury is then underestimated when using STANAG Trauma Code 4 (intentionally self-inflicted) in the hospitalization data as a case definition. However, there is no better source from which to acquire this incidence information.

Effect-Measure and Interpretation Issues

Any "effect" in this study should be construed as merely a statistical relation between dependent and independent variables, as the variables of interest are generally considered potential risk factors, not necessarily causal factors. For instance, a mental health hospitalization itself was not causative; however, the underlying pathology responsible for that hospitalization probably *was* causal. This is discussed in more detail later. The hospitalization incidence (discussed above) does not represent the incidence or onset of the condition for which hospitalization occurred, merely the incidence or frequency of being hospitalized for a prevalent condition that has reached a relatively high level of clinical complexity or severity, at least in most cases. We have no information on the duration of the illness or the "survival" of servicemembers with prevalent mental health disorders; therefore, an estimate of disease incidence is not possible from this study regardless of how one defines incidence of these disorders. Survival in the context of a military population not only entails death and suicide, but "administrative censoring" through medically-related involuntary separation from the service due to the condition. Outpatient data representing lower severity would be needed to more accurately measure the prevalence or incidence of mental health disorders.

Competing Objectives for Multivariate Modeling

Multivariate models in this study were designed for two purposes: to ascertain independent risk factors and to predict suicidal events. Given the dual purpose, we attempted to strike a balance between the parsimony of risk factor modeling and the all-inclusive nature of prediction models. Our models are intended to be used "in the field"

where data processing capabilities may be limited, thus we limited the number of terms in the models to only those terms which were efficient contributors to the predictions. These "efficient" terms, as a result of this efficiency, were those which also qualified as independent risk factors. As an example, our completer multivariate model predicted 60 suicide completions (see below) using nine terms which generated 97 unique covariate patterns (using a predicted probability cutoff of 0.50). Using a model with 39 terms (including dummy variables) with 1,991 covariate patterns predicted only three additional suicides out of the 502 that were committed throughout the USAF (with over 80 bases) during the study period.

PREDICTION MODELING

The case-control based prediction models correctly classified 82 percent of the study subjects at the 0.5 level of probability (of being a case), but were plagued by the combination of low sensitivity and high "false negative" rates. Our highly sensitive (low predicted probability) models predicted most of the true completers or attempters, but that large net caught an abundance of "false positives" as well. The highly-specific (high predicted probability) models (cutoff = 0.70) were successful in excluding most of the false positives, but they also failed to predict the vast majority of true positives. The attempter model's "positive" classification is 90 percent accurate at a probability as low as 0.76. However, that still translates into a sensitivity of only about 12 percent, with 990 out of 1,132 attempters falsely classified as "negative". Such is often the dilemma with prediction models for suicide, even when overall accuracy is high (Goldstein et al. 1991). Prediction capability further erodes when individuals fall into one of two mutually exclusive categories (completers/attempters and controls in our study) in which one group (controls) outnumbers the other (Carrera 1992). In our study where four out of every five subjects is a control, it was easier to predict who did not commit a suicidal act than who did. Still, the models performed better than guesswork at determining which subjects were among that 80 percent. Chapter 4, *Discussion*, discusses the utility of the models.

We also believe that many, if not most, of our high probability controls will have attempted or completed suicide outside the USAF. Serious attempters and non-attempters with poor mental health are high priority targets for involuntary separation from the USAF, likely resulting in significant losses to follow-up. These losses represent a strong bias, in that their suicide probabilities are likely far greater than those who remain under observation. As a result of this censoring, our models are probably more valid than our results indicate.

Policy Implications

MORTALITY REGISTRY JUSTIFICATION

The mortality data comparison in Chapter 2 did more than contribute to a better analytical study in Chapter 4. The study also documented the existence of the AFMR and its superiority for USAF injury prevention research. The AFMR provides a template for a DoD mortality registry which has been in the discussion phase for the last few years. Multiple-cause of death information clearly provides more information to injury researchers and gives the USAF the capability to conduct mortality surveillance in the same manner as NCHS does for the general U.S. population. Unfortunately, military deaths cannot be reliably identified in NCHS data. We recognize that death certificate information has its own limitations (Rosenberg and Kochanek 1995) in injury prevention research, so the ideal mortality registry would also bring in other information sources including Casualty's summary of the forensic investigation, Safety Center event-related data, and psychological autopsy information. This large body of narrative text information would resemble the National Institute for Occupational Health and Safety's National Traumatic Occupational Fatalities System (NTOF). NTOF has been extremely useful in that its narrative data allows researchers to examine fatalities in greater detail that is generally available in coded mortality information (Stout and Jenkins 1995). We see no reason to constrain the validity and depth of epidemiological information by limiting the data source to death certificates,

particularly when that information is already available. However, the AFMR in its current format will at least allow epidemiologists to compare the rates and trends of specific-cause injuries both internally and to that of the U.S. population. The ideal mortality registry would also include retirees, so that "survival" estimates would include those individuals lost from the Casualty reporting system due to their abrupt involuntary retirement, many who were in the process of dying. We hope that the military epidemiology and prevention community will use our findings to further justify an all-service mortality registry.

Contagion and the Propagation of Suicidality

Some evidence of short-lived contagion following suicidal events on bases or within units was noted. Unit-level commanders should anticipate that one event will likely warn of a second or third event within the next 3–4 days, as the rate of suicidal activity (completions and attempts) generally increases three- to five-fold over the rate before the most recent event. Commanders should work with mental health personnel to develop a remedial suicide intervention plan which could be implemented expeditiously following an event at their base. Such a plan would be designed to de-fuse the intentions of others to imitate suicide. However, Durkheimian theory suggests that prompt population-based remedial efforts such as we suggest above may be futile (Maris 1997), as the concept of imitation is dismissed.

The continued propagation of suicide attempts throughout the 90-day period following an exposure suggests that the base-level psychosocial environment, not the event-exposure, is the contagion; and, this causal inference *does* conform to Durkheim's (Simpson 1951) beliefs. The base-level (or unit's) environment is the appropriate target for many of the USAF Suicide Prevention Program's efforts, and further enhancement strategies should continually be explored.

The Air Force's suicide prevention program is currently targeting several issues that this study addresses, particularly regarding contagion. The program's emphasis on increasing social support mechanisms and removing barriers to seeking mental health

services should improve the psychosocial environment at USAF bases. Betterment in that area should lessen servicemembers' pathological identification with adverse conditions, lessening the contagion seen in the more impressionable and younger attempters.

Reducing Injury Misclassification

The Air Force, if not the entire military, would benefit by policies aimed at reducing injury intent misclassification. Given the level of suspected injury misclassification, the incidence of attempts is probably higher than what we were able to present. Suicide attempts, recognized or not, remain the strongest risk factor (and predictor) for completed suicide in most retrospective studies (Moscicki 1997), and the absence of prior suicide attempts as a risk factor for completed suicide in this study is conspicuous. The current Suicide Prevention Plan's objective to improve access to mental health practitioners should not only be directed at prospective patients, but to the general medical staff as well. Medical clinicians obviously need greater access to mental health consultation on at-risk patients, as we have described them in this study, including those who are more frequently hospitalized. This additional consultation would likely recognize additional suicide attempters who could receive timely intervention. Perhaps a standard protocol could be developed for the most efficient and effective use of mental health consultants. Hospitalizations for occupational injuries which are coded as unintentional are probably valid classifications in most cases, but non-occupational "accidents" should probably be regarded as potentially intentional depending on the external cause, particularly if the injured is male. The index of suspicion seems particularly high for poisonings, and at least moderate for hospitalizations due to falls and motor vehicle mishaps, depending on the circumstances (e.g., single vehicle, single occupant motor vehicle mishap) in both sexes.

Unintentional injuries will always be a military public health problem in their own right, but misclassified hospitalizations may be overestimating the magnitude of that problem—while underestimating the intentional injury incidence—at the highest levels of injury severity. Injury misclassification has material implications in prevention planning, as

strategies designed to reduce the incidence of unintended mishaps are obviously different than preventive approaches for suicides or suicide attempts.

Screening for Overseas Assignment

The medical screening process for overseas assignment should be critically reviewed with regard to mental health requirements. This study infers that current screening policies are not successful in sending only the most resilient individuals into overseas or operational environments. Perhaps abusers of alcohol, at risk for suicide, are often not identified before they transfer overseas or deploy. Additional screening tools (e.g., the military's health risk appraisal, outpatient treatment information) should be considered. Screening for suicidal tendencies should be incorporated into the medical standard of care regardless of assignment status, particularly if individuals carry key risk factors identified here and in other studies.

Utilization of In-patient Services

The increased risk of suicide with increased utilization of in-patient services (and contact with medical authorities) may be interpreted two entirely different ways, as discussed above. Additional research is needed to determine the most appropriate policy pathway on this "retention or prevention" issue. Regardless of the interpretation of this finding, it does indicate the need for a policy review: consider an earlier threshold for involuntary medically-related discharges from the USAF, or place greater emphasis on suicide intervention within the clinical arena, or both.

Prevention Targeting

Prevention planners can use the findings of this study to more effectively define and target higher risk groups comprising of common risk factors, using the linear combination of odds ratios from the multivariate independent risk factor models. Each USAF medical treatment facility has access to these same data sources for their catchment region. Local data could be used to identify "enriched risk pools", demographic

categories (groups) on which to apply more targeted preventive mental health services. For instance, enlisted unmarried white males in their thirties who have recently been hospitalized for an alcohol-related problem are about 10 times as likely to commit suicide that persons without those risk factors.

Additional Risk Factor Research

Perhaps other measurable risk factors will be found which will increase the discriminatory power of these models. One recently-published prospective study in the U.S. Army identified another suicide risk factor, cigarette smoking (Miller et al 2000). Smoking 20 or more cigarettes per day emerged intact from a multivariate model as an independent risk factor (twice the risk compared to never-smokers), using a field of covariates similar to ours. Unfortunately, were not able to examine this association with our data.

Suicide Prevention Strategies

As stated previously, this research is intended to assist military mental health practitioners and prevention officers to deliver more targeted services to those individuals or groups in which the suicide risk is greatest. The risk factors (and those found to be protective) for suicide and attempted suicide found in this study are summarized in Table 1 below. Some prevention planners may search Table 1 for causal mechanisms and conclude that nothing is there on which to prevent suicide. I counter that argument below.

A statistical relation between a specific factor and (para)suicide does not need to be causal to identify high-risk individuals, a worthy objective of any suicide prevention effort. The linear combination of risk estimates from specific risk factors may be used to identify individuals or (more preferably) groups at varying degrees of risk of committing a suicidal act, as suggested above. Each risk group could receive tailored prevention services along an intensity gradient which is customized. In other words, the type, intensity, and level of services would be matched to the level of statistical risk. Higher risk groups, generally smaller in size, would receive more intensive intervention, including clinically-

based services. Groups with more moderate risk levels could receive increasingly broader-based services. Low risk groups would still receive the current program's intended modifications of the base-level psychosocial climate.

In searching for casual mechanisms, one needs consider the pathology behind those risk factors (Table 1), particularly those based on hospitalizations. Each risk factor identified in this body of research is a proxy for a single potentially modifiable and necessary cause among a constellation of other necessary causal factors for some proportion of suicides or attempts. While we have not identified (or indirectly inferred) all of the necessary elements, we need only to mitigate the effects of *one* of the necessary components to prevent a given set of suicidal acts (O'Carroll 1993). If Causal Factor A is implicated in 15 percent of suicides, eliminating Factor A will decrease suicide incidence by the same percentage. O'Carroll recommends using a combination of the strength of the association (odds ratio in our study) and the prevalence of a particular causal factor in the general population to aid in selecting causal elements for preventive intervention, i.e., the population attributable risk percent or etiologic fraction (Rothman and Greenland 1998). It may be calculated as

$$[b(RR-1)/b(RR-1)+1] \times 100$$

where *b* equals the proportion of the population exposed to the causal element and *RR* is the relative risk associated with that causal agent, approximated by the incidence rate ratio in Chapter 3 and the odds ratio in Chapter 4. As an example, successful early intervention in alcohol abusers which prevents progression to the level of severity requiring hospitalization (history of alcohol-related hospitalizations OR = 7.4, proportion exposed = 0.5%) could potentially prevent 3.1 percent of USAF suicides, or about two per year on the average. Similar treatment successes for *all* mental health disorders (OR = 13.8, proportion exposed = 0.9%), or alternatively, an environmentally-induced decrease in the incidence of those disorders at that level of severity, could potentially prevent 10 percent of suicides in

the USAF population, or 5–6 per year during the study period. These successes could prevent 17 percent of suicide *attempts*, using the same computational methods. This example hypothetically assumes that disorders of lower severity (non-hospitalized) do not proceed to suicide or suicide attempts.

Clearly, the USAF's intent to address the base-level psychosocial environment (theoretically decreasing the incidence of mental health disorders) and improved access to clinical mental health services (halting the worsening of existing conditions) will have a greater impact on reducing suicide incidence than concentrating solely on alcohol abuse prevention and treatment. Both measures can (and do) co-exist and are complementary; however, the population-based approach (primary prevention) may be expected to pay a bigger prevention dividend than a more clinically-focused effort towards treating alcohol abusers (secondary prevention). The prevention possibilities in the examples above may appear relatively modest in the overall USAF population, but "they all add up" to more impressive numbers. Additionally, one or more sub-groups may derive greater benefit from a particular prevention program element. Such is the case in the *all mental health disorders* example above, as 18 percent of female suicides could be prevented.

O'Carroll's (1993) conclusion is that prevention planners should not necessarily be dazzled by high measures of association and focus solely on the putative causal element most strongly associated with suicide. Causal elements with strong statistical associations do not always account for many deaths, and some with more modest associations may be more prevalent in the general population, "exposing" more people. Also, the strongest causal factor may not be the most amenable to prevention efforts. Modifiability and the cost of the intervention are two important criteria to use in deciding which factors to attack (O'Carroll 1993).

Keeping the two criteria above in mind, the USAF would be well-served by improving the overseas assignment screening process. Mental health practitioners could select a valid alcohol screening instrument which could detect potential alcohol abusers before they are assigned overseas. One study used four such instruments in a trauma

center setting (Soderstrom et al. 1997), illustrating the availability of valid screening devices. USAF mental health officials should evaluate each instrument's potential for use in screening the general population. The current system, primarily a medical records review (which may not include mental health records), is apparently not sensitive enough to effectively identify individuals prone to alcohol abuse who may also be at risk for suicide, particularly under the stresses of living and working overseas. Otherwise, the process selects individuals for those assignments who appear to be more resilient against mental illness and suicide than those assigned stateside. Whatever additional cost the USAF incurs by administering the additional screening would be defrayed by the lower incidence of alcohol-related hospitalization and suicidal acts.

Table 1. Summary of findings in descriptive (Chapter 3) and analytical (Chapter 4) studies: risk factors and protective factors for suicide and attempted suicide, USAF 1990–1998

Key to symbols is at end of table.	SUICIDES					ATTEMPTS		
	Descriptive		Analytical			Analytical		
	Crude	Multi-var *	Crude	Bivar Adj †	Multi-var*	Crude	Bivar Adj *	Multi-var*
Factor								
<u>Socio-demographic Factors</u>								
Male	++	.	++	++	.	−−	−−	−−
Enlisted	++	.	++	++	.	++	++	++
Male X Enlisted	.	++	.	.	+++	.	.	.
Age 17–19	−−	.	−−	−−	−−	++	++	++
Race = White/non-Black	++	++	+	+	++	−	−	.
Married	.	.	−−	−−	−−	−−	−−	−−
Occupational groups (all)	N	N	++ (some)	++ (some)	.	++ (some)	++ (some)	.
Less than 1 yr in military	.	.	++	++	++ ¶	++	++	++ ¶

Key to symbols is at end of table.	SUICIDES			ATTEMPTS		
	Analytical			Analytical		
	Crude	Bivar Adj †	Multi-var*	Crude	Bivar Adj *	Multi-var*
EXPOSURES, PROXIMAL						
Recent deployment (last 6 months)	N	N	.	–	–	– –
Assigned overseas	–	N	–	+	–	++
Assigned to a Pacific base	–	–	.	+	++	.
Assigned to other overseas area	N	N	.	N	N	.
Tactical base assignment	–	–	.	+	+	.
BRAC assignment	+	+	.	+	+	.
Hospitalization, medical	++	++	++	++	++	.
Hospitalization, alcohol	+++	+++	++ ‖	+++	+++	++ ‖
Hospitalization, reactive depression	+++	+++	.	+++	+++	+++ ‖
Hospitalization, stress/adjustment disorder	+++	+++	+++ ‖	+++	+++	++ ‖
Suicide attempt	+ ‡	.	.	+++	+++	+++
Hospitalized, "accident"	++	++	++	++	++	.
Time since exposure (trend from 0–90+ days)§	N	N	N	++	++	++

Key to symbols is at end of table.	SUICIDES			ATTEMPTS		
	Analytical			Analytical		
	Crude	Bivar Adj †	Multi-var*	Crude	Bivar Adj *	Multi-var*
EXPOSURES, PRODROMAL						
Hospitalized, medical	+	+	.	++	++	++
Hospitalized, mental health (any diagnosis)	+++	+++	+++	+++	+++	+++
Hospitalized, psychosis	+++	+++	.	+++	+++	.
Hospitalized, neurosis	+++	+++	.	+++	+++	.
Hospitalized, stress	+++	+++	++ ‖	+++	+++	++ ‖
Hospitalized, alcohol	+++	+++	++ ‖	+++	+++	++ ‖
Hospitalized, depression	+++	+++	++ ‖	+++	+++	++ ‖
Suicide attempt, ever	+ ‡	.	.	+++	+++	+++ #
Hospitalized, both injury and mental health	++	++	.	++	++	.
Deployed any time during period	+	+	.	– –	– –	.
Hospitalized, "accident"	++	++	++	++	++	.
Hospitalized, accidental poisoning	+++	+++	.	+++	+++	.
Hospitalized, accidental fall	++	++	.	++	++	.
Hospitalized, motor vehicle accident	+	+	.	++	++	.

Key to symbols is at end of table.	SUICIDES				ATTEMPTS		
	Analytical				Analytical		
	Crude	**Bivar Adj †**	**Multi-var***		**Crude**	**Bivar Adj ***	**Multi-var***
Hospitalized, machinery/tool accident	+	+	.		+	+	.
Hospitalized, sports injury	+	+	.		–	–	.
Hospitalized, other accidental injury (weapons, drowning, environmental, water transport)	N	N	.		–	–	.

Key:

N No association (OR/IRR = 1.0)

– OR/IRR protective but statistically insignificant (OR/IRR< 1.0)
– – OR/IRR significantly protective

\+ Risk factor (OR/ IRR>1), non-significant
++ Significant risk factor, and OR/IRR 1.1–5.9
+++ Significant risk factor, and OR/IRR ≥ 6.0;

. = Variable not assessed in those analyses, or term dropped from multivariate model (see † below)

** Multivariate analysis: statisitical models with full set of risk factors and adjustment variables; . indicates covariate dropped from due to model insignificance from likelihood ratio testing.*
† Bivariate analysis, adjusted for multiple socio-demographic characteristics.
‡ Odds ratio undefined since no controls had a prior suicide attempt (low frequency cells).
§ Time since exposure categories: 0–7 days, 8–30 days, 31–90 days, beyond 90 days.
|| Significant to multivariate model only when ANY MENTAL HEALTH HOSPITALIZATION removed.
¶ Significant to multivariate model only when AGE and RANK related covariates are removed; collinear with those terms.
 # Significant to multivariate model only when RECENT SUICIDE ATTEMPT (proximal exposure) removed.

Several risk factors seen in this study are not directly modifiable, yet they provide clues on other factors which may be amenable to prevention. Assignment overseas or to Pacific bases (currently South Korea, Japan, Guam, Hawaii, Alaska; also The Phillippines during the early part of the study period) in particular, to tactical unit bases, or to bases which are being readied for closure are all unavoidable since these bases require personnel in order to be operational. These risk factors suggest that the psychosocial environment at those types of bases may need more immediate attention when applying the elements of the USAF Suicide Prevention Program.

If the USAF adopts a more focused suicide prevention strategy, planners should avoid the allure of so-called precipitating factors. While they may be competent predictors of suicidal events (e.g., recent alcohol-related hospitalization), their more powerful prodromal/distal counterparts (e.g., ever hospitalized for alcohol-related problems) offer more opportunity for reducing the suicide incidence (Moscicki 1994). O'Carroll's cost-effectiveness criterion notwithstanding, "preventive interventions may need to be as complex, intensive, and long-term as those behaviors they are intended to prevent in order to have lasting effects" (Moscicki 1994). These measures should also address several risk factors simultaneously, as described below.

> "For example, suicide prevention efforts need to be embedded in programs that address distal risk factors such as mental health and substance abuse, as well as proximal risk factors such as responsible firearm ownership". (Moscicki 1994)

Conclusion

This study was the first to demonstrate the use of linked large administrative databases for acquiring risk factors for suicide and attempted suicide in the military. It was also the first to use *multiple cause of death* mortality information, obtaining that data from the AFMR.

Results indicated, first, that the AFMR was the most valid and reliable source of mortality information for the USAF. Significant improvement in the specificity of the external underlying cause of death for injuries was documented, as compared to the usual source of military injury mortality information (the Casualty system). A DoD mortality registry has been debated for years, and our study provides the most convincing evidence to date that the often-used Casualty system is inadequate for epidemiological research. Using the AFMR, we constructed a more complete case series of suicides for the study, largely due to the "120-day retiree" sub-cohort. Omitting this group from military mortality research, as has always been the case, introduces a systematic information bias to such research that may be avoided by using the AFMR. Any effort to replicate the AFMR in the other military services—highly recommended in the short term—should ensure that those medically-retired servicemembers are followed up. Such observation need not stop at the 120-day point, as that follow-up period is merely arbitrary.

Bivariate analyses provided evidence of multiple proximal and prodromal/ distal risk factors for both suicide and attempted suicide. Suicide attempts had largely been ignored in previous military injury research. Multivariate analyses indicated that completers and attempters had several independent risk factors in common, but the socio-demographic risk factors were altogether different. In other words, attempters and completers represent different sub-groups of the USAF population. Prodromal (prevalent) factors—largely depicted by a history of mental health-related hospitalization—comprised the bulk of the independent risk factors. Injury-related hospitalizations were also statistically correlated with subsequent attempts and completions. The absence of a "biological" explanation of this relation indicated that many intentional injuries (concealed attempts) were likely to be misclassified as accidents, particularly in males who are hypothesized to be more covert in their intent. Contagion borne of the base-level psychosocial environment was indicated, although evidence also existed of a brief period of the imitative form of contagion. The analyses in Chapter 4 are preliminary, not a definitive cluster analysis, thus

more work is needed to analyze both suicide completions and attempts in relation to space and time

The risk of suicidal activity increased with increased levels of in-patient service utilization for most diagnostic categories. This finding for mental health hospitalizations indicates treatment failures and possibly missed opportunities for prevention. For non-psychiatric conditions (i.e., medical, injury) the results suggest that screening these patients for suicidal risk factors is warranted.

Deeper exploration of several statistical relations indicated that overseas assignment screening was allowing a significant percentage of the "less resilient" to evade detection (and stateside treatment), particularly those prone for alcohol abuse. Several assignment-type suicidal risk "hot spots" were recognized, areas which may require special attention from prevention specialists.

Despite constructing a model with good statistical parameters in general, our predictive models failed to effectively discriminate between cases (completers or attempters) and the controls from the general USAF population. Several potential sources of good data are available which could provide some of the apparent missing covariates needed to build a better prediction model. The constraint on the number of variables available in our available data sources is perhaps the study's primary weakness. Still, this study provided encouraging results that key suicide prevention information may be obtained from military corporate information systems.

Several key findings provide medical and mental health policymakers with information that was previously unknown or undocumented. The recent growth in military medical information technology will most certainly add to this knowledge and will allow military officials to refine current suicide prevention strategies, further reducing suicide's toll on the armed forces.

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AFEB Injury Prevention Work Group to the AFEB)

CURRICULUM VITAE

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ACADEMIC TRAINING

PhD – Injury Epidemiology. The Johns Hopkins School of Hygiene and Public Health, Baltimore MD

MPH – Epidemiology. The Johns Hopkins School of Hygiene and Public Health, Baltimore MD

MA – Geography/Environmental Planning. Eastern Kentucky University, Richmond, KY

BS – Environmental Health Sciences. Eastern Kentucky University, Richmond, KY.

RESEARCH EXPERIENCE

Chief, Research and Epidemiology Branch; Plans and Policy Division, U.S. Air Force Safety Center; Kirtland AFB NM (September 2000–present)

- Conduct epidemiologic research using multiple, linked injury surveillance and administrative (e.g., demographic and health system) databases, leading to findings applicable to injury prevention strategies and policies throughout the USAF. Scope includes both ground and aviation/flight mishaps, and both unintentional and intentionally-inflicted injuries.

- Member of several DoD injury and occupational illness prevention committees and work groups.

Doctoral Student, Injury Epidemiology, Center for Injury Research and Policy, The Johns Hopkins University School of Public Health, Baltimore MD September (1997–August 2000)

- Sponsored by the U.S. Air Force for doctoral-level training in injury control/ prevention, and epidemiology.

- Conducted risk factor research on USAF suicide and attempted suicide; wrote 5 manuscripts within the research protocol.

- In-residence military consultant on several military injury mortality research efforts.

APPLIED RESEARCH EXPERIENCE

Public Health Epidemiologist, USAF Office for Prevention and Health Services Assessment (OPHSA), Armstrong Laboratory, Brooks AFB TX (November 1995 – September 1997)

- Project Manager (Principal Investigator, Brooks AFB Protocol #97-19), Air Force Mortality Registry Demonstration Phase. Developed and executed a research protocol for developing a prototype Air Force mortality registry, using the complete multiple cause of death information from death certificates collected by the Air Force Health Study (Project Ranch Hand) on active duty and recently-released servicemembers.

- Team Member (co-investigator), USAF Morbidity, Mortality, and Disability Study, the first comprehensive use of several USAF administrative data systems.

- Project Manager for the TRICARE Regional Immunizations Tracking System. Developed functional requirements for DoD's current immunizations tracking software; used currently-available modified commercial software applications to operate a prototype system within DoD Healthcare Region 10, Travis AFB CA.

- Project Manager, Reportable Event Surveillance Software Project: successfully developed and fielded a fully-automated, state-of-the-art reportable event surveillance system using USAF-developed software.

- Team member, Health Enrollment Assessment Review (HEAR) Project. USAF/Battelle/CDC Team developed the first DoD-wide managed care enrollment questionnaire. Currently used DoD-wide for both enrollment and as a health risk appraisal instrument.

- Tri-service team member, Defense Medical Epidemiological Database (DMED). Developed methods for constructing a research database for epidemiologic use consisting of several linked DoD corporate and medical databases. Currently in use world-wide by subscription, and produces standard queries using the Defense Medical Surveillance System.

- Project Officer, USAF Safety Center Epidemiologic Consultations. Formed and led a team of military and civilian experts in injury epidemiology to provide input to USAF's injury prevention agency on their operations in injury surveillance, research objectives, and prevention program targeting. Led to staffing changes to include on-site military epidemiologists. Recruited an epidemiologist for that agency.

- Team Member, USAF Behavioral Risk Factor Surveillance Survey. In close collaboration with the CDC, the team modified the national BRFSS to administer throughout the Air Force (by the University of Texas), allowing behavioral comparisons between the military and the civilian population. USAF team determined sampling methods; CDC analyzed the data in same manner as the national survey.

- Adjunct Instructor, US Air Force School of Aerospace Medicine (USAFSAM): Primary instructor for the Operational Epidemiology Course given to public health officers and selected physicians. Instructor for the DoD Global Medicine Course in epidemiology, primarily for military flight surgeons.

PUBLIC HEALTH SURVEILLANCE EXPERIENCE

Senior Public Health Epidemiologist, Epidemiologic Research Division, Armstrong Laboratory, Brooks AFB TX (August 1994–November 1995)

- USAF's primary surveillance and disease outbreak investigator officer; constructed and managed the USAF's current reportable disease surveillance system.
- Managed the following special purpose USAF surveillance systems: Human Immunodeficiency Virus (HIV); Worldwide Influenza Surveillance (in collaboration with CDC and WHO on the scope and substance of the surveillance); Pediatric Blood Lead Screening Program; Emerging Infectious Diseases
- Wrote quarterly and yearly analytical reports for the Air Force Surgeon General on the results of surveillance operations. Disseminated public health surveillance information to USAF bases, major commands, and HQ Air Force Medical Operations Agency (AFMOA)
- Adjunct instructor and curriculum advisor to the USAFSAM's Operational Epidemiology Course; provided instruction in other courses throughout USAFSAM.

TEACHING EXPERIENCE (FULL-TIME)

USAF Public Health Officer; Director, Epidemiology Curriculum, Department of Military Public Health and Occupational Medicine, USAF School of Aerospace Medicine, Brooks AFB TX (June 1993–August 1994)

- **Instructor.** Department's primary instructor and subject matter expert for instructional blocks in basic epidemiological methods, applied epidemiology, environmental sciences and medical intelligence. Developed, reviewed and updated public health officer curriculum in epidemiology including educational objectives, lesson plans and test materials for each block of instruction.
- **Course Supervisor**, Operational Epidemiology. Designed course, determined scope and level of training needed for epidemiological practice in military operation. Developed academic plan and courseware from multiple sources including CDC Epidemic Intelligence Service (EIS) case studies. Matched instructors with periods of instruction, using School and adjunct faculty
- **Medical Intelligence Officer.** Accessed classified and non-classified intelligence reports, evaluated information in those reports for relevance in School-wide training; give this information to course supervisors and department chairpersons on a need-to-know basis for inclusion into instructional blocks

PREVENTION PROGRAM MANAGEMENT EXPERIENCE

USAF Public Health Officer, Assistant Chief–Chief, Military Public Health Service
Assignments: Whiteman AFB, MO; Howard AFB, Panama; Travis AFB CA
(November 1985–June 1992)

- Managed multiple primary and secondary prevention programs and assigned personnel at base-level. Programs covered: reportable event surveillance (primarily acute infectious diseases); environmental sanitation; food safety; occupational health surveillance and training; medical entomology; hospital/clinical employee health. Managed clinical (screening, diagnostic, treatment, and interview) programs for sexually-transmitted diseases and tuberculosis.

- Performed epidemiological investigations of diseases with public health significance including outbreaks.

- Member, infection control committee; served as hospital epidemiologist; assured appropriate post-exposure follow-ups (e.g., TB, hepatitis B, HIV) when warranted using computerized tracking program.

Medical Intelligence Officer. (Additional duty at all locations served)

- Conducted risk assessment of infectious diseases for units deploying to overseas or combat theater locations; formulated preventive medicine protocol (education, prophylaxis/vaccination, avoidance, medical follow-up). Briefed commanders and units prior to deploying.

Chief, Environmental Health and Industrial Hygiene (Environmental Science Officer), U.S. Army Medical Department Activity, Preventive Medicine Service, Fort Polk LA (April 1983–November 1985)

- Managed programs in community drinking water surveillance, facility environmental sanitation, industrial hygiene, community health, and environmental quality at a large mechanized infantry post. Managed EPA-certified community water bacteriology laboratory.

- **Safety and Radiation Protection Officer**, Bayne-Jones Army Community Hospital. Monitored large military hospital for compliance with federal occupational health and safety regulations; performed surveillance and epidemiological analysis of occupationally-related injuries and illnesses; participated in NIOSH study on ethylene oxide.

PUBLIC HEALTH SUPPORT DURING CONTINGENCY OPERATIONS

Chief, Environmental Health Team/Medical Medical Intelligence Officer (deployed "in place"), Howard AFB, Republic of Panama, during Operation Just Cause (1989–1990)

- Designed and implemented wartime public health surveillance during Operation Just Cause for both U.S. troops and refugees. Designed and implemented preventive medicine regimens in refugee camps, troop field housing, and in U.S. detainee camps. Consultant on the sanitary engineering of those camps in accordance with Geneva Conventions and United Nations requirements. Operated a temporary morgue and performed superficial forensic investigation.

- Consultant to *Aedes aegypti*-Dengue Fever Eradication Project, a joint venture between U.S. Southern Command and Panama Health Ministry, post-conflict period in Panama, 1990.

Chief, Environmental Health Team/Medical Intelligence Officer (deployed), RAF Nocton Hall, UK, during Operation Desert Storm (1991)

- Developed and implemented a disease surveillance network for a 750-bed NATO contingency hospital; monitored food and water supplies for potential terrorist chemical or biological sabotage.
- Prepared multi-national hospital staff for possible receipt of patients with incubating disease from biological agents.

PUBLICATIONS/MANUSCRIPTS

Copley GB, Smith GS. Suicidal Activity in the U.S. Air Force, 1990–1998: A Nested Case-Control Study of Risk Factors Obtained Through Administrative Databases. *In Progress*

Copley GB, Smith GS. Suicide in the U.S. Air Force, 1990–1998: Descriptive Epidemiology Using Death Certificate Multiple-Cause Information. *In Progress*

Copley GB, Smith GS, Grayson JK. Comparison of the Level of Agreement Between Two Sources of U.S. Air Force Injury Mortality Data. *In Progress*

Copley GB, Smith GS. Improved Military Mortality Surveillance Using Multiple Cause of Death Information. *In Progress*

Copley GB, Smith GS. Unintentional Injury Mortality in the U.S. Air Force: Descriptive Epidemiology Using Multiple Cause of Death Information. *In Progress*

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Grayson JK, Miller JM, **Copley GB**, Robbins AR, Lombard D, Marshall M & Mellman J. The health of the USAF 1995: The Morbidity, Mortality, and Disability Study. Brooks AFB Texas, 1996

HONORS AND AWARDS

Army Commendation Medal, 1985
Air Force Commendation Medal, 1988
Air Force Commendation Medal (First Oak Leaf Cluster), 1990
Air Force Meritorious Service Medal, 1993
Air Force Meritorious Service Medal (First Oak Leaf Cluster), 1995
Air Force Meritorious Service Medal (Second Oak Leaf Cluster), 1997

COMPUTER SKILLS

Stata Statistical Software; Epi Info; Microsoft products: Excel, Word, Access, Project; WordPerfect; ProCite (bibliographic)